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Editor
ROY WALDO MINER

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SECTION OF GEOLOGY AND MINERALOGY

RECENT DEVELOPMENTS IN SEISMOLOGY*

By J. Joseph Lynch

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While seismic investigation of a sort has been carried on since the first century of the Christian era, organized seismology really began with the formation of the Seismological Society of Japan in 1880. Oddly enough, its founders were not Japanese but an American, Colonel Van Buren, American Consul General in Tokyo, and an Englishman, John Milne, later Sir John Milne, professor of engineering at the Imperial University. Their purpose in founding this first seismological society in history was to lessen, if possible, earthquake disaster in Japan.

Before turning to modern developments in seismology, I think it will be helpful to review the early findings of organized seismology. By 1900, after approximately 20 years of comparing notes, it was found that two waves were propagated through the earth from the center of an earthquake. These waves were identified by Professor Wiechert in Gottingen, in 1907, respectively as compression and shear waves. By this time, fairly reliable travel-time curves for these waves had been obtained. These travel-time curves, however, gave no clue to the velocity of the waves or their path. They were merely curves plotting arcual distance from the quake against time. If earthquake waves travelled an arcual path, such curves, of course, would give the true velocity of the waves, but it was known that earthquake waves travelled through the earth from earthquake to recording station and not merely around the surface. The first real feat of the seismologist was to compute from these surface travel-time curves the actual velocity of the waves at all depths. From the theory of elasticity, it is now known that the ratio of the velocity of these two waves is 1.7 to 1 or $\sqrt{3}:1$. The compression wave, the faster of the two, has a speed of about six km. per second at the surface of the earth. This speed increases to eight km. per second at the base of the crust, thence from 8 to 14 km. per second (gradually) as we descend to the core. At the core of the earth, *i.e.*, about half way down, the wave velocity decreases from 14 back to 8 km. per second, then increases again from 8 to 11 km. per second at the center of the earth.

The first contribution of organized seismology was, of course, a fairly accurate catalogue of earthquakes and accurate maps showing the geographical distribution of quakes. These records were compiled by timing

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on May 2, 1955.

the arrival of the primary and secondary waves at the various stations. This time interval, measured by means of the travel-time curves just mentioned, allowed the distance of a quake from each observatory to be easily determined. Geographical location of the quake was calculated by drawing circles on a globe with the observatories as centers and their distances from the quake as radii.

The second contribution was definitely to establish the existence of a core in the earth at a depth of 2900 km. or, roughly, half-way down. While the existence of the core had been suggested previously on other grounds, real proof came only from seismology. Existence of the core was first intimated to the seismologist by the existence of a blind spot or, rather, a blind belt around the earth. Specifically, for every quake there is a belt around the earth extending roughly from 105 degrees to 140 degrees, within which the primary wave is not recorded. This seemed to indicate that the waves were being refracted away from observatories in this belt. The denser core was suggested as being the refracting medium, and this was verified when waves reflected from the core were picked up at the expected times.

While the primary and secondary waves were the chief tools of the seismologist, there were, of course, other waves. The primary and secondary waves are called body waves because they travel through the body of the earth. A third group of waves travels around the outside surface of the earth. Their speed—about two miles per hour—is slower than that of the body waves. Investigation showed these waves to be of two kinds. One group has a vertical component and resembles surface water waves. Its waves have a regressive motion, *i.e.*, they roll in an ellipse backwards from the direction in which they are travelling, *i.e.*, forward, upward, backward, and down. They are the Rayleigh waves, so called after Lord Rayleigh, who deduced a mathematical explanation for their existence. The second group has no vertical component. It consists of shear waves, the motion of the earth particles being transverse in the plane of the earth's surface. These waves are somewhat faster than the Rayleigh waves and are called Love waves after the English mathematician who supplied a mathematical theory for their existence, or Q waves (for Querwellen) because of their transverse character. On Love's theory, the velocity varies with wave length, the shorter waves approaching the velocity of shear waves in the upper layer, the longer waves approaching the velocity of shear waves in the lower layer. While the Rayleigh waves have a velocity of nine tenths that of the shear waves, the Love waves have the velocity of shear waves, but this varies somewhat with wave length.

Perhaps the third contribution of seismology to our knowledge of the earth was the discovery, in the 1920's, that earthquakes occur at varying depths down to more than 500 miles. The author was studying with

Professor Turner at Oxford in 1920 when Turner published this suggestion of deep focus earthquakes. Turner was led to the suggestion by the failure to locate geographically about 5 to 10 per cent of the earthquakes in a year. The travel-time curves on which the distance of a quake is computed are drawn on the assumption that the quake occurs at the surface of the earth. If the quake does not occur at the surface, but some 500 miles below the surface, clearly surface travel-time curves will not give the correct distance. Turner noticed that in these irreconcilable quakes some stations gave too great a distance, and some the correct distance from the quake when its geographical position was known. In practice, those stations in good agreement with each other were used to determine the distance and time of origin of the quake. Then a suitable depth of focus was adopted to bring the other stations into line. This hit-and-miss method worked well but was tedious. Other methods were soon introduced to determine the depth of focus more quickly and more accurately. In these later methods, use is made of the fact that, in the case of a deep focus quake, shortly after the arrival of the direct compression wave a second wave arrives which has been reflected from a point on the earth's crust near the epicenter. This wave is designated pP to distinguish it from the regular reflected P wave PP which is reflected from a point midway between epicenter and station.

In recent years, further earthquake waves have been discovered whose explanation is not yet clear. In general, the two body waves, P and S, give rise to reflections both from surface and core and to refractions through the core. All these have been well accounted for. In 1935, attention was called by Father D. Linehan[1] to an entirely new phase. Since it followed the P and S waves and looked somewhat like them in character, he called it the T, or third wave. There is still lack of agreement as to its physical explanation. It is a short period phase of less than half a second, found on the vertical records of submarine quakes and travelling more slowly than P and S. Ewing,[2] following his extensive work on the Sofar channel in water—a channel of low velocity at 700 fathoms in which sound is channelled to great distances, with little loss of energy—suggested that this T phase is, in fact, a sound wave channelled through the Sofar channel. Instances have been cited where background noises in the Sofar channel were traced to earthquakes many miles inland. Confirmation for Ewing's theory has come from investigation of earthquakes travelling great distances overland with P velocity before entering the water and thence travelling in the Sofar channel.[3] The chief objection to this theory has resulted from too poor an agreement between observed and calculated travel times.[4,5] The theory, however, has by no means been disproved. Hence, it seems safest here to mention the existence of the T phase and leave its final explanation to the future.

Along the lines of the Sofar channel in water, Gutenberg recently suggested a similar low-velocity channel in the crust for earthquake waves. For many years, serious discrepancies were noticed between the velocity of compression of waves obtained from artificial explosions and blasts and those obtained from natural earthquakes. The velocities of waves from artificial sources were always unaccountably higher than those from natural quakes. Moreover, epicentral determinations from P and S waves in local quakes were never in very good agreement with each other. In an attempt to resolve these difficulties, Gutenberg suggested that there might be a layer of low velocity for P waves at a depth of 10 to 15 km. below the surface. A physical basis for such a low-velocity channel is to be found in experimental indications that some materials, notably quartz, undergo a decrease in elastic constants at increasing temperature and pressure approaching those at a depth of 10 hours in the earth.

Following this suggestion of Gutenberg, Ewing and Press[6] found evidence of two slow surface waves crossing the North American continent with speeds of three and one-half and three km. per second respectively. They named them L_g and R_g—Love and Rayleigh waves, the subscript g indicating that their path might lie in the granitic layer. Lehmann[7] later confirmed the existence of these waves and, more recently, Båth[8] has found similar waves across Euroasiatic paths. It seems reasonably well established, therefore, that the low-velocity channel suggested by Gutenberg does exist, and that it acts as a wave guide for waves following continental paths much as the Sofar channel is a wave guide for water waves.

Summing up the seismic waves regularly recorded now at seismic observatories, we have:

P	Compression 8 km. per second.
S	Shear 5 km. per second.
T	A slow compression wave following an oceanic path 1.5 km. per second.
LQ	A Love surface wave 4.5 km. per second.
LR	A Rayleigh surface wave 4.0 km. per second.
L_g	A Love continental wave 3.5 km. per second.
R_g	A Rayleigh continental wave 3.0 km. per second.

The suggestion in recent years that there is a core within a core lacks sufficient evidence to warrant more than mere mention here.

Microseisms continue to offer one of the most fertile fields for seismic investigation. At the Session on Microseisms held in Rome, Italy, in September 1954, it was unanimously agreed that, despite considerable success in tracking hurricanes by microseismic technique, it is at present impossible to locate the center of a hurricane by microseisms if it is far out to sea. Only near-shore centers can be so located.

Microseisms are now known to cover a spectrum from a small fraction of a second to periods of 20 seconds. Since 1947, we have made exhaustive studies of two-second microseisms associated with cold fronts. Their speed, at least in the New York area, is about one-half mile per second. Our conclusion about their mechanism is as follows. A cold front, moving down from polar regions and meeting warmer air over the Great Lakes, generates sizable wave action on the surface of the lakes. These progressive waves, on reaching the shore, are reflected and give rise to standing waves on interfering with the approaching direct waves. These standing waves, pounding the lake bed, give rise to ground microseisms which travel across the continent with a speed of one-half mile per second, thus giving warning of the approach of the front. When the front itself reaches the Atlantic, it gives rise to further microseismic activity by setting up standing waves in the Atlantic. We have observed, both visually and instrumentally, four-second progressive waves on Lake Michigan. These, according to the Longuet-Higgins theory, should give rise to two-second standing waves which, in turn, should give rise to two-second continental microseisms.

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*SECTION OF BIOLOGY**

SOME FACTORS AFFECTING THE GROWTH OF NORMAL HUMAN EPITHELIAL CELLS *IN VITRO* **

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In an earlier report,[1] a method used successfully in the continuous subcultivation of epithelial cells derived from normal human tissues was described. By this method, four lines of epithelial cells have been established from normal human conjunctiva, liver, kidney, and appendicial mucosa, and subcultivated serially from 35 to 50 times. In the course of this study, it was observed that serums obtained from various donors differed markedly in their ability to support the multiplication of these cells, and that the rate of multiplication varied greatly even when experimental conditions were carefully controlled. It also became quite apparent that the careful evaluation of factors affecting the growth of these cells depends largely on the availability of a simple method for the quantitation of cell multiplication.

The cell-count method, used by other investigators[2-5] in the study of mouse fibroblast, mouse lymphosacoma, human cervical adenocarcinoma, and monkey kidney, has been adapted to quantitate the multiplication of the epithelial cells derived from normal human tissues. In essence, the method consists of the preparation of a homogeneously dispersed cell suspension, the inoculation of an equal number of cells into sets of four roller tubes containing media whose effect on these cells are being studied, and the enumeration of cells in each tube after incubation at 36°C. for seven days.*** The mean number of cells per tube and its standard deviation is calculated for each set of four tubes. The results are then compared with the standard control.

When the conjunctival cells are cultivated in a medium containing 20 per cent human serum, 5 per cent chick embryo extract and 75 per cent balanced salt solution with 0.001 per cent crystalline soya bean trypsin inhibitor, the rates of multiplication of these cells vary greatly in the serums from several donors, and also in serum obtained on different occasions from the same donor (TABLES 1 and 2). Inactivation of serums

*The Section of Physics and Chemistry held a meeting on May 3, 1955 at which a paper entitled "The Mechanisms of Some Metal-Ion Promoted Reactions" was read by Frank W. Westheimer. No abstract of this paper has been received.

**This paper, illustrated with lantern slides, was the first of two papers presented at a meeting of the Section on May 9, 1955.

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***Medium in each tube was changed on the third and fifth day.

at 56°C. for 30 minutes destroys some growth promoting properties (TABLE 3). The conjunctival cells do not multiply significantly faster in media containing 40 per cent human serum than in media with 20 per cent human serum. However, when the serum concentration of the medium was reduced to 10 per cent or 5 per cent, the rate of multiplication is significantly reduced (TABLE 4). Two batches of chick embryo extract stored at –20°C. for 1 and 10 months are superior in promoting growth of conjunctival cells to one batch of beef embryo extract stored at –20°C. for five months (TABLE 5). Similar results were obtained when another two batches of chick- and beef-embryo extracts were compared.

TABLE 1

EFFECT ON THE MULTIPLICATION OF CONJUNCTIVAL CELLS OF SERUMS FROM FIVE DONORS

Donor	No. of cells (10^3) per tube after 7 days at 36°C.	Mean
Mu.	65, 69, 92, 70	70
Te.	17, 11, 4, 18	13
Mo.	34, 19, 18, 26	24
Ch.	18, 6, 14, 19	14
Fr.	18, 19, 22, 26	21

Inoculum = 9.2×10^3 cells per tube.

TABLE 2

EFFECT OF SERUMS OBTAINED AT DIFFERENT TIMES FROM SAME DONORS

Donor	Date	No. of cells (10^3) per tube after 7 days at 36°C.	Mean
Mur.	1/28/55	67, 61, 82, 89	75
	1/18/55	128, 183, 129, 135	144
	11/ 5/54	63, 81, 80, 55	70
Moo.	9/30/54	41, 34, 58, 55	47
	12/ 8/54	61, 74, 88, 67	73
	2/11/55	85, 66, 60, 41	63

Inoculum = 6.8×10^3 cells per tube.
Date tested, Feb. 15, 1955.

TABLE 3

EFFECT OF INACTIVATION OF SERUMS

Donor	Inactivation	No. of cells (10^3) per tube after 7 days at 36°C.	Mean
Moo.	Yes	41, 34, 58, 55	47
	No	77, 63, 71, 70	70
Mur.	Yes	67, 61, 82, 89	75
	No	98, 108, 91, 88	96

Inoculum = 6.8×10^3 cells per tube.

In our earlier report,[1] it was stated that these epithelial cells were maintained in good morphological state for, but not longer than, two or three weeks in the synthetic medium, MS(3), with 20 per cent horse serum. In these earlier studies, pooled serums from several horses were generally used. It was later discovered that, by careful pretesting, serums from certain horses were found capable of supporting the growth of these epithelial cells in the absence of human serum. FIGURE 1 shows the multiplication of the conjunctival cells in four different media (5 per cent human serum, 20 per cent horse serum, 5 per cent chick embryo extract and 79 per cent MS; 20 per cent human serum, 5 per cent chick embryo extract and 75 per cent balanced solution; 20 per cent horse serum, 5 per cent chick embryo extract and 75 per cent MS; 20 per cent horse serum, and 80 per cent MS). It was evident that the growth is fastest in medium consisting of 5 per cent human serum, 20 per cent horse serum, 5 per cent chick embryo extract and 70 per cent MS, and slowest in 20 per cent horse serum in MS. Growth in the standard medium, or 20 per cent human serum, 5 per cent chick embryo extract, and 75 per cent balanced salt solution is only slightly faster than in 20 per cent horse serum, 5 per cent chick embryo extract, and 75 per cent MS. The conjunctival cells have been subcultivated serially five times without any apparent ill effect in medium consisting of 20 per cent horse serum, 5 per cent chick embryo extract, 75 per cent MS, and 0.001 per cent soya bean trypsin inhibitor.

TABLE 4

EFFECT OF CONCENTRATION OF SERUM IN MEDIUM

Donor	Serum Conc.	No. of cells (10^3) per tube after 7 days at 36°C.	Mean
Moo.	40%	114, 103, 122, 89	107
	20%	77, 80, 110, 95	91
	10%	41, 55, 35, 41	43
	5%	30, 47, 36, 30	36
Haak	40%	44, 63, 45, 34	46
	20%	35, 27, 42, 91	36
	10%	51, 53, 49, 35	47
	5%	25, 12, 21, 10	17

Inoculum = 13×10^3 cells per tube.

TABLE 5

GROWTH PROMOTING PROPERTY OF CHICK- AND BEEF-EMBRYO EXTRACT

Extract	Length of storage	No. of cells (10^3) per tube after 7 days at 36°C.	Mean
Chick	1 month	77, 80, 110, 95	91
Chick	10 months	79, 83, 85, 89	84
Beef	5 months	56, 51, 39, 48	49

Inoculum = 13×10^3 cells per tube.

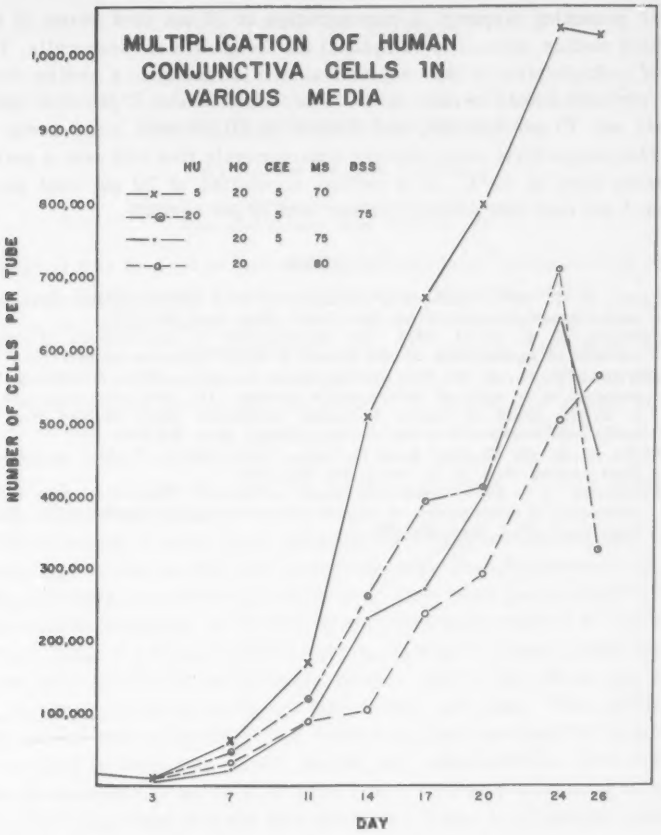

FIGURE 1. Multiplication of conjunctiva cells in various media.

The addition of 0.005 to 5 units of insulin per ml. of medium, of 0.001 to 0.1 μg. of crystalline thyroxine and 0.001 to 1.0 μg. of hydrocortisone does not influence the rate of multiplication of the conjunctival cells. Thyroxin at a concentration of 1 to 100 μg. and hydrocortisone at 10 to 100 μg. suppress the growth of the conjunctival cells.

Summary

Some factors affecting the growth of epithelial cells derived from normal human conjunctiva *in vitro* are studied quantitatively. Serums from several donors varied greatly in their ability to promote the growth of these epithelial cells as did serums obtained from a single donor on separate occasions. Inactivation of serum at 56°C. for 30 minutes destroyed some

growth promoting property. A concentration of 20 per cent serum in the standard medium seemed to be optimal for the growth of these cells. The rate of multiplication of the conjunctival cell is fastest in a medium made of 5 per cent human serum, 20 per cent horse serum, 5 per cent chick extract and 70 per cent MS, and slowest in 20 per cent horse serum in MS. The conjunctival cells multiply approximately five-fold over a period of seven days at 36°C. in a medium consisting of 20 per cent horse serum, 1 per cent chick-embryo extract and 79 per cent MS.

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SECTION OF BIOLOGY

SUBCUTANEOUS GROWTH OF NORMAL AND MALIGNANT HUMAN TISSUES IN HETEROLOGOUS HOSTS*

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Since it was first noted that normal and malignant human tissues could be grown subcutaneously in the X-irradiated laboratory animal [1, 2] and also in cortisone-treated hosts, [3] a number of human neoplasms have been developed as transplantable tumors for regular laboratory use.[4] Several of these have been transferred in animals for over two and one-half years and are now in quantity production. Indeed, the amount of one of these tumors (H.S. No. 1) harvested from rats and hamsters in our laboratory alone, is often as much as three pounds per week of solid tissue. It is noteworthy that the original specimen of this neoplasm weighed less than half a gram.

These human tissues have retained their original morphology, their human-type chromosomes (as contrasted with the chromosomes of the rats, hamsters, or chicks in which they have been propagated**), and their human antigens, as tested by the agar-plate method of Ouchterlony. [5] Once the human tissues have sojourned in animals, they can be grown with relative ease in tissue culture[6] and in the chick egg, both on the chorioallantoic membrane and in the yolk sac.[7] The ability of both normal and malignant human tissues to grow more rapidly in animal hosts than in their own human source and, subsequently, after one or more generations in animals, to grow better in tissue culture or in eggs than when implanted directly from the human donor, is of special interest and has been discussed elsewhere in some detail.[4] In brief, a possible explanation for this phenomenon might be made in terms of the loss of the human stroma after implantation of the human tissue in animals, as the stroma is always replaced in any animal-to-animal transfer of tissue. If this stroma had a species-specific inhibitory effect on the panenchymal cells, then no inhibition would be operative by its removal. Thus, in animal hosts, the human parenchymal cells could realize their full proliferative potential. On the basis of this explanation, successful tissue-culture and egg transfer of human tissues could be accomplished also if human stromal elements were first removed by a sojourn in animal hosts.

*This paper, illustrated with lantern slides, was the second of two papers presented at a meeting of the Section on May 9, 1955.

**A. R. T. Denues, F. Mottram, and J. J. Biesele. Personal communication.

Metastases of the human tumors in their heterologous hosts occur infrequently or frequently according to the individual neoplasm. H.S. No. 1 (a sarcoma), for example, is usually localized at the site of implantation even though it may attain a weight of 8 to 12 gm. in the two-week period before death of the host. Metastases are seldom seen. H.Ep. No. 3 (an epidermoid carcinoma), on the other hand, is highly invasive and metastasizes widely when implanted in either the rat or the egg. In the latter case, if the chick is able to hatch, it will usually be riddled with metastatic nodules, especially in the brain, heart, lung, and liver. This particular tumor also shows promise of being the first transplantable human tumor in ascites form, as it grows intraperitoneally in the free-cell state in mice as well as in rats and hamsters.

All the tumors can be transferred freely from cortisone-treated hosts to tissue culture, to egg, and back again to animals. It should be emphasized, however, that at no time have the animal tissues been grown successfully in untreated, control-animal hosts. Such growth would be undesirable, as it would indicate that the human antigenicity had been lost or altered. Lack of any growth in the control animals is especially noteworthy in view of the fact that, in the case of the tumors with a tremendous growth potential, *e.g.*, H.S. No. 1 and H.Ep. No. 3, only 3 mg. of cortisone given to the hamsters at the time that the tumor is implanted in the cheek pouch is sufficient to ensure progressive growth of the neoplasms until death of the host. Such mortality occurs approximately 14 to 16 days after implantation, from anemia and general cachexia, secondary to the large tumor mass. It is believed[8] that the initial dose of cortisone in these animals abrogates the natural immunity that may be present in the form of heteroagglutinins such as have been described in the rat.[9] Once the tumor is established, it is able, by reason of its proliferative capacity, to overcome any resisting forces later mustered by the host (acquired immunity). In short, the antigen/antibody ratio, if one thinks of the tumor/host relationship broadly in such terms, is all in favor of the antigen.

Not all the transplantable human tumors, and none of the normal tissues, can be maintained on one 3-mg. dose of cortisone in the hamster. The human embryonic and normal adult tissues, as well as such comparatively slow-growing tumors as H.Ep. No. 1 and H.Ep. No. 2 (both epidermoid carcinomas), would regress if the hamster host did not receive an additional 1 mg. of cortisone approximately every fifth day. A few tumors, such as H. Emb.Rh. No. 1 (human embryonal-rhabdomyosarcoma), are "borderline." They may or may not be able to grow progressively until death of the hamsters on the one initial cortisone dose. Rats always require more cortisone treatment to support the human tissues than do hamsters. At the present time, rats receive one total body X-irradiation dose of 150 r. any time up to a week prior to

implantation plus three or four doses of cortisone of 3 mg. each on alternate days, beginning with the day of implantation. They may also be conditioned, if X-irradiation is omitted, by increasing the cortisone doses to 6 mg. each. Such a concentrated treatment usually renders these hosts unsuitable for experimental use. These hosts are mainly used, therefore, as "stock" and "screening" hosts because they are easily handled and prepared. The hamsters, requiring but a small conditioning dose, are ideal for experimental use. Furthermore, when the human material is placed in their pouches, it can be everted, examined, and returned intact at any time by anesthetizing the host. Hamsters also require no X-irradiation.

All the animals used, whatever the species, are of weanling age, for such animals support the growth of human tissues most readily. Adults or nursing babies have not proved as susceptible to conditioning with either X-irradiation or cortisone. Immature animals have one further advantage over adult hosts in that they lend themselves more readily to studies of hormone effects on the tumor growth.

Though malignant tissues have formed the bulk of human material "screened" for possible proliferation in heterologous hosts, normal adult tissues, *e.g.*, skin[2] and thyroid, have been grown as well. Embryonic human tissues are especially easy to cultivate.[10] These proliferate more slowly than the tumors and are thus maintained, by choice, in the cheek pouches of hamsters, which tolerate small but continued amounts of cortisone given over long periods of time. Human embryonic lung has now been kept in excellent, progressively proliferating condition for as long as six months in the same hamsters. The embryonic tissues show continual differentiation. In the case of the lung, however, an apparently abrupt differentiation to a postnatal-type lung morphology occurs almost immediately after implantation. This is due to a distention of the very immature aveolar tubules to a more adult conformation of aveoli. Fluid, not air, is contained within them. Comparatively slow-growing tissues, such as the embryonic, the normal, and some malignant human tumors, offer good opportunities for long-term experiments.

A few general notes may be made on the types of tumors grown and the techniques associated with their optimal maintenance other than conditioning of the hosts. To date, it seems possible to obtain at least some proliferation of almost any type neoplasm, though at least some, such as the mammary adenocarcinomas and melanomas, seem to present special problems. These problems are now under investigation.[11] The epidermoid carcinomas, as a group, are by far the easiest to grow. They remain in good condition hours after removal from the patient. This is in marked contrast to the adenocarcinomas of the bowel, which must be transplanted almost immediately or fail to grow. It is likely that the

tumors, such as those of the digestive tract, which contain enzymes, are self-autolytic and thus by their very nature are difficult to cultivate. Such problems inherent in the tumors *per se* (the brain tumors when transplanted to subcutaneous sites may also be included in this category) are of prime importance to the new investigator in this field, and they must be considered by him in the evaluating of his success or failure to obtain heterologous transplants. Aside from such consideration, it is desirable at all times to obtain material as fresh as possible and free from infection (for this purpose nodules of metastatic tumor are especially valuable). Rapid and sterile techniques in implantation are also important. In our laboratory, the minced-cell suspension injected by a No. 18 needle, even in the hamster pouch, has always proved more successful than the trocar piece, which may fail to vascularize, or the cell-press suspension, in which much of the material is damaged or destroyed.

That these animal-carried human tissues have proved to be useful in the laboratory is indicated by their ever-increasing use for experimental purposes as more material becomes available.[6, 7, 12, 13] That the method of growth is practical is shown by the ability of other investigators, using these techniques, to develop new transplantable human tumors of their own.[14, 15]

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SECTION OF PSYCHOLOGY

THE OPERANT, FROM RAT TO MAN: AN INTRODUCTION TO SOME RECENT EXPERIMENTS ON HUMAN BEHAVIOR*

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Virtually all psychologists accept the premise that human behavior is orderly. The order that they see, however, varies considerably from group to group, and the aspects of behavior in which these orders appear differ as well. The clinician and the personality psychologist observe their fellow men and see need-presses, repressions, and agressive drives. The experimental psychologist finds his order in the rates at which nonsense syllables are learned, or at which conditioned eyelid reflexes are acquired. If he is physiologically oriented, he is apt to concern himself with muscle twitches and even with the secretion of saliva. It is in terms of such variables that psychologists have set their descriptions of, and their predictions about, the actions of people.

All of us, whether psychologists or not, observe people acting. We learn rules of "practical psychology." Some of us, especially the novelists and playwrights, do a remarkably good job of giving plausible accounts of behavior, often in terms that seem pertinent. These writers, however, do not employ the language used by psychologists at either end of the spectrum. They describe ordinary, everyday behavior, and describe it well, but not by using the conceptualizations that psychologists seem to have found useful, nor even terms that can be readily translated into such conceptualizations.

The psychologist's efforts tend to be limited in their usefulness to the description and prediction of the behavior of people whose behavior is awry, or of people who are engaged in the strange and unusual activities demanded of them in a laboratory of experimental psychology. Dale Carnegie, practical politicians, and, perhaps, everybody *but* psychologists, concern themselves with simple, ordinary, everyday behavior. One reason for this situation is, perhaps, the lack of methods of conceptualizing behavior, or of abstracting relevant aspects of behavior for study that are not clinic- or laboratory-bound. This lack of methods is due, perhaps, to a conviction that ordinary behavior is too complex and is determined by too many variables to make possible the discovery of any order except by the application of theory.

What I desire to do here is to introduce some concepts, and to describe some experiments derived from them, that suggest that the orderliness of human behavior may be more accessible than has been hitherto assumed.

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on May 16, 1955.

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These experiments may accordingly suggest new directions for research on human behavior.

A number of years ago, in a series of articles that were summarized in his book, *The Behavior of Organisms* (1938), B. F. Skinner introduced two new concepts into the behavioral sciences. These concepts had familiar names, but their experimental and theoretical content represented a sharp break with the past, a break that had been foreshadowed only in the writings of Kantor (1924).

The first of these concepts is that of the operant response, defined as a part of behavior (a) that is recurrently identifiable and hence enumerable; and (b) whose rate of occurrence can be determined as a systematic function of certain classes of environmental virables. These parts of behavior, or actions, are what we can see an animal perform repeatedly. They are not simple muscle twitches or limb movements. Rather, they are meaningful, repeated actions. They constitute bar presses rather than leg extensions, the picking up of food rather than digital flexions, the speaking of words rather than laryngeal contractions. One class of environmental variable of which such responses are functions represents the second new concept. This is the reinforcing stimulus, defined as a recurrently identifiable and experimentally manipulable part of the environment that has the property of modifying the rate of occurrence of those operant responses that have produced it. Like responses, they are parts of the environment that are meaningful to the animal, not abstract physical events. They are doors, spoken words, food, not the energy patterns that concern sense physiologists. The two concepts are closely related to one another, so much so, in fact, that many writers, including Skinner himself, often state that operant responses are defined by their consequences, that is, by their production of a given reinforcement. Without going into detail on the experimental and theoretical questions involved in this statement, let me single out for elaboration certain properties of these concepts that distinguish them sharply from those other concepts of stimulus and response that have been widely understood—and even more widely misunderstood—by both psychologists and laymen.

The first of these properties is this: it is not possible to determine arbitrarily and a priori what recurrently identifiable parts of behavior will prove to be responses—that is, what parts of behavior will obey the empirically established laws of behavior. True, within limits, an experimenter may "shape" a part of behavior by differential reinforcement, and thus may be able to introduce a new response into the animal's repertoire, but his ability to do so is sharply limited by the animal itself. Animals of each species, each with its own individual history, come to the experimenter with a repertoire of operant responses that the experimenter can analyze and, within limits, modify. By and large, however, the experimenter must work with those responses that he finds in the

animal's behavior. Not all recurrently identifiable behaviors are responses. After observation, the sophisticated experimenter will often be able to guess which identifiable parts of the animal's behavior will prove to be responses, that is, will vary as particular functions of reinforcing stimuli.

Similarly, the experimenter does not have unlimited latitude in determining a priori what environmental events he can use as reinforcing stimuli for an animal. As with responses, he can convert, to a limited degree, originally neutral events into reinforcing stimuli. To do this, he must follow certain experimental procedures. There still remains, however, the empirical problem of determining the whole class of events that will reinforce an already identified response of his experimental subject. Again, as with response, the sophisticated experimenter often will be able to guess which of the environmental events that he can make dependent on a response will produce changes in the rate of occurrence of that response in the period following the occurrence of the environmental event.

With some reason, operant responses have been characterized as "spontaneous" or "voluntary." They are what the animal does "by himself." This is not to say that operants are independent of the ordinary laws of elicitation (and hence of our usual conceptions of causality in behavior) but rather that, for all practical purposes, the only control the experimenter has over them is the one he exerts by the operation of reinforcement, that is, by presenting the animal with a reinforcing stimulus following the occurrence of the response.

In tackling any new piece of behavior experimentally, or in starting to study the behavior of a previously uninvestigated species, the experimenter has a double problem. He must find responses, and he must find reinforcing stimuli that control their occurrence. More often than not, he designs experiments that involve the simultaneous identification both of the operant responses and of the reinforcing stimuli by demonstrating orderly changes in the rate of some part of behavior that are contingent upon the association between that part of behavior and a specific environmental change. A bar press is a response, and food is a reinforcing stimulus, because when bar presses produce food, the rat presses the bar more frequently. By the same rules, water is a reinforcing stimulus for a thirsty rat, whose response may be the sticking of its nose in one corner of the cage.

In view of these systematic restrictions, one is not surprised that almost all studies of operant conditioning have been made on two responses and on two species. The bar pressing of hungry rats and the key-pecking of hungry pigeons, both with reinforcement by food, have been experimentally studied on a scale that, to put it mildly, is intensive. A few other responses from a few other species, involving a few other reinforcing stimuli, have been studied, but not very extensively.

In any case, a very large body of experimental evidence has been amassed on the operant (Keller and Schoenfeld, 1950; Skinner, 1938; Skinner, 1953b), and behavioral psychologists may take some pride in the number of stimulus-response laws that have been found.

The problem arises, however, of the relationship of this body of experimental data, and the laws derived from it, to human behavior. For those investigators interested in men, wherein lies the relevance of these laws? Several kinds of attempts have been made to exhibit such relevance. The first of these may be termed "extrapolation by analogy." The theorist hypothesizes that certain kinds of human behavior are responses and that certain kinds of events are reinforcing stimuli for humans. The rat- and pigeon-derived laws are then assumed to apply, and a set of statements about human behavior are generated that satisfy the writer and his friends, and that horrify others or (what is worse) leave them cold. This has been the history of Skinner's *Walden Two* (1949), and of his *Science and Human Behavior* (1953a).

The second tactic is to elaborate a rather complex theoretical structure and then to spell out predictions of human behavior that may or may not be experimentally testable. This, too, has produced books (*e.g.*, Miller and Dollard, 1947) that edify or horrify, depending on the reader.

A third procedure is an experimental one. In this, one studies human behavior in the laboratory under conditions that parallel as closely as possible the experimental procedures followed for the lower animals. Very simple responses are studied, and very simple reinforcers are used. In 1942, Warren and Brown (1943) conditioned children to press a lever, using candy as a reinforcing stimulus. Since then, a number of responses have been conditioned, usually involving tapping a telegraph key or the like as response and, with food, the registration of a number, or the playing of music as reinforcer (*e.g.*, Lindsley, 1954; Green, 1955). The studies have shown clearly the reproducibility in human subjects of the laws of operant conditioning found to obtain in rats. These methods, however, leave something to be demanded. The relevance of pressing-a-key-for-a-piece-of-candy to most everyday human behavior may be questioned, and the vexing problem of "awareness" enters, so that a variety of "interpretations of the results" are possible. It may reasonably be questioned whether a human subject, under observation and engaged in unfamiliar activities in a laboratory, will behave as he would if he were not in such a special situation.

The fourth tactic is the one that is the subject of this paper. This is the identification of responses and of reinforcing stimuli, and the verification and eduction of laws relating them to one another in human behavior under conditions where the subject is acting as naturally as possible, and where, insofar as possible, he is not "aware" of what is going on. The approach is characterized by a broad increase in the classes of both responses and reinforcing stimuli investigated, and by a

controlled relaxation of the rigorous (and very probably irrelevant) environmental controls exerted in the laboratory.

The first such investigation was that of Greenspoon (1950). From his observations of "nondirective" therapy, Greenspoon suspected that the therapist's "mmm-hmm" was a reinforcing stimulus and, hence, that it modified the verbal behavior of the client undergoing therapy. He proceeded to test this notion in the laboratory by instructing each of his large (separately run) number of subjects to say as many different words as they could. He further assumed that *saying plural nouns* was a response, and proceeded to show that the relative frequency of plural nouns in the subject's verbal behavior was a function of the experimenter's manipulations in reinforcing the subject by casually murmurring "mmm-hmm" each time he said one. Greenspoon went on to discover several other reinforcing stimuli. In the data he reported, none of his subjects was aware that his behavior had changed as a function of reinforcement. None seemed to notice the experimenter's "mmm-hmm's," even though his behavior changed as a function of them.

In 1951, we tried to repeat the Greenspoon experiment in a class at Harvard. The experimenters had had very little previous work with human conditioning. They were game, however, and cornered their subjects in a variety of places. The results were interesting and instructive. A few experimenters obtained unequivocally positive results, but not always without the subject becoming aware of the reinforcements. The successful experimenters were the most prestigeful, socially adept individuals, and the unsuccessful ones tended to be those of what might be termed lower prestige. At the same time, attempts were made to condition simple motor behavior, using reinforcers such as "mmm-hmms," smiles, and "good." The results, as with verbal behavior, were indifferent.

Therefore, a new tack in the research was taken. In an attempt to pin down the relevant variables, we reverted to the study of simple motor behavior, and modified the procedure to ensure that subjects responded to the reinforcing stimuli (the experiments described here are more fully reported in a paper now in press: Verplanck, 1956a). Subjects were instructed explicitly as to the environmental changes that the experimenter would manipulate, although no information was given them as to the behavior the experimenter would reinforce. After finding a fellow student who was willing to be a subject, the experimenter instructed him as follows: "Your job is to work for points. You get a point every time I tap the table with my pencil. As soon as you get a point, record it on your sheet of paper. Keep track of your own points." With these instructions, it seemed likely that a pencil tap, a "point," would prove to be a reinforcing stimulus. The method worked very well. Indeed, the experimenters were now able to condition a wide variety of simple motor behaviors, such as slapping the ankle, tapping the chin, raising an arm, picking up a fountain pen, and so on. They were further able to differ-

entiate out, or shape, more complex parts of behavior, and then to manipulate them as responses. The data they obtained included the results on the manipulation of many of the variables whose effects were familiar in operant conditioning of rats and pigeons. Despite the fact that the experiments were carried out in a variety of situations, the experimenters were able to obtain graphical functions that could not be distinguished from functions obtained on the rat or the pigeon in a Skinner box.

To be sure, the responses studied in humans were very different from the key pecking of a pigeon, or the bar pressing of a rat, and a point is a very different event from the arrival of a pellet of food in a food hopper. But the general laws relating those parts of behavior demonstrated to be responses to those environmental events shown to be reinforcing stimuli were the same.

More interesting, there appeared to be no fixed relationship between the conditioning effects and the subject's ability to state verbally the response that the experimenter was reinforcing. That is, the subjects were responding in a lawful and orderly way without necessarily being aware of what they were doing. They were not necessarily "figuring it out."

With these results, we were encouraged to proceed in two directions. First, we returned to the Greenspoon experiment and repeated it with certain refinements of design, and with experimenters who had acquired considerable experience in the conditioning of human motor behavior. These results are reported elsewhere (Wilson and Verplanck, 1955), but they may be summarized briefly here: experienced experimenters had no difficulty in reproducing the changes in rate of saying words of particular classes that Greenspoon reported. The experimenters' "mmm-hmm," although uttered without instructions and introduced as if unintentionally, modified the subjects' behavior, whether or not the subject noticed it. Subjects usually were aware of the reinforcing stimuli, however, and, at the end of the experiment, would tend to report something such as, "I noticed that you seemed to like nouns for a while, and that then you didn't care."

The second direction was forward, and it took a long step beyond the chin tappings and word sayings that had been shown to be responses. For a number of reasons (not the least of which was a set of encouraging results from an exploratory experiment), we hypothesized that in an ordinary conversation, saying sentences of a particular class would act as a response, and that agreement by a hearer, or paraphrasing back to the speaker by a hearer, would prove to be reinforcing stimuli to the speaker.

Two experiments were done. In the first, the response reinforced was *stating opinions*, where opinions were defined as sentences beginning "I think that," "I believe that," and the like. In the second, the response reinforced was *making any statement on a preselected topic*, the

topic being chosen by the experimenter and introduced into the conversation by him in a sentence requiring no answer.

The experiments were carried out in a series of 44 conversations that took place on a wide variety of topics and in a variety of circumstances. The sole restriction on the experimenter was that he carry out the experiment with only himself and the subject present, and under conditions where he could keep accurate but camouflaged records of the subject's behavior. He was also under intructions to terminate the experiment if the subject gave any indication that he suspected that this was anything other than an ordinary conversation.

The results of these experiments were unequivocal. In the first experiment, on opinion-statements, every one of 23 subjects showed a higher rate of giving opinion-statements during the 10-minute period when the experimenter reinforced each of them by agreeing with it, or by repeating it back to him in paraphrase, than he showed in the first 10-minute period, when the experimenter did not reinforce. In a final 10-minute period, 21 of 23 subjects showed the converse effect, termed extinction, that is, they decreased in their rate of stating opinions when reinforcement was withdrawn. Irrespective of topic of conversation, or of the situation in which the conversation took place, the expected changes in rate occurred, under conditions where not one subject gave any indication, at any time, that he was "aware" of the experimental manipulation. The subjects' behavior, an orderly function of the experimenters' actions, followed the laws of reinforcement without any awareness by the subject, even of the fact that he was in an experiment.

In the second experiment, the experimenter introduced the experimental topic at the end of the first 10 minutes of conversation. Some subjects (N = 6) were controls, and were not reinforced through the following 10-minute period. The others (N = 15) were regularly reinforced. Under these conditions, every subject but one replied to the experimenter's sentence introducing the topic. Those who were not reinforced dropped the topic quickly (within 2 or 3 minutes), whereas those who were reinforced shifted their speech so that almost everything they said through the next 10 minutes of conversation fell into the specified response-class. In all cases, on the withdrawal of reinforcement, and without respect to whether statements on other topics were reinforced, the subjects dropped to a rate of zero on the previously introduced and reinforced topic.

Again, no subject gave evidence of being aware in any way that this was not an ordinary conversation.

These experimental results indicate that our hypotheses with respect to the analysis of conversational speech into response and reinforcing stimuli were justified. One example of complicated, superficially variable human behavior proves simple under experimental analysis. Order is readily demonstrable. The time may hence be ripe for an extension of experimental analysis into other areas of human behavior that have

been considered unsusceptible to direct experimental investigation.

Orderly, significant data *can* be collected in situations devoid of the elaborate environmental controls exerted in the laboratory if significant variables are manipulated, if measures of that behavior are possible, and if experimental designs are clear-cut. Experiments can be performed on human subjects "in the field" and under conditions where the subject will not be able to discriminate either his own or the experimenter's behavior as dependent on an experimental procedure. Hence we can study human behavior with good reason to hope that the mere fact that it is being investigated will not modify it. This alone has seriously limited the generality of the many results of laboratory experiments.

One can now conceive of a broad experimental program designed to determine what other parts of behavior have the functional properties of responses, and how broad a class of environmental events will prove to be reinforcing stimuli for one or another subject. The conceptual tools are at hand. The experimental methodology, involving a number of sophisticated and skilled experimenters, is at hand. A very rapid development in this field may be expected. We may hope for an experimental, rather than an 'intuitive,' understanding of many of the things that people do.

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SECTION OF MATHEMATICS AND ENGINEERING

THE HIGHWAY SPIRAL AND THE OSCULATING CIRCLE*

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The best known and most widely used transition curve for highways is the clothoid, first investigated by Leonhard Euler, the Swiss mathematician. This curve is mathematically exact, and tables exist which permit precise field layout with a minimum of computation, provided such layout proceeds from the curve's point of beginning, commonly referred to as the T. S. (tangent to spiral).

When it is necessary to lay out the spiral from a point on the spiral other than the T.S., or to connect with a spiral two circular curves of different radii, mathematical exactness gives way to the approximations of the theory of the osculating circle. The theory works well for flat spirals, but is unsatisfactory for sharper spirals. This paper establishes a mathematical background for the theory and provides a simple, yet accurate, method of determining the extent of the approximations for any given spiral.

By definition, the degree of curvature of the clothoid varies directly with the length measured along the curve. Elements of the clothoid are shown in FIGURE 1. The degree of the clothoid is 0° at A and varies directly with length to the degree of the circular curve BG at B. The full central angle is θ_s, and the central angle to any point, P, is θ. The deflection angle to P is ϕ. Point C on circular curve BG produced backwards, is called the offset T.C. (tangent to curve). The offset, CD, is given the symbol p.

When two circular arcs of different radii are to be connected, only a portion of the clothoid shown in FIGURE 1 is used. Thus, a 200-foot transition from a 4° to a 6° circular arc is the last third of a 600-foot clothoid running from a tangent (circular arc of 0°) to a 6° circular arc. To distinguish between the abbreviated clothoid and the clothoid of which it is a part, the former will be called a combining spiral and the latter a simple spiral.

A combining spiral is shown in FIGURE 2. The spiral is the full curve from A to B joining circular arcs GA and BH. The circular arcs have been extended to C and D where their radii are superimposed. The offset, CD, between the two curves is required to permit insertion of the spiral. The offset for the combining spiral will be designated by the symbol p_s to distinguish this offset from that of the simple spiral. Central angles $DO'B$ and AOC are designated α and β respectively.

*This paper was presented at a meeting of the Section on May 20, 1955.

The deflection angle from the tangent at A or B to any point P on the spiral is ϕ_a.

The theory of the osculating circle states that the spiral departs from the osculating circle at the same rate that the spiral departs from the tangent at its point of beginning. In FIGURE 3, which shows an enlarged portion of FIGURE 2, the deviation of the spiral from an osculating circle at A is shown. Arc AP on the spiral, and arc AQ on the osculating circle have the same length, l. The angle PAQ or ϕ is, according to the theory, equal to angle DAP in FIGURE 1 provided the length of arc AP in FIGURE 1 is also equal to l. The deflection angle ϕ_a, from the tangent at A to point P on the combining spiral (FIGURE 3) is the difference between two easily computed angles, the deflection angle to the osculating circle and the deflection angle from the T.S. of a simple spiral to a point the same distance, l, from the T.S. If the degree of the spiral is increasing in the direction of layout, ϕ_a is equal to the sum of these two angles.

The theory further assumes that angles α and β are equal to Δ_1 and Δ_2, respectively, with

$$\Delta_1 = \frac{D_1 L_a}{200} \qquad (1)$$

and

$$\Delta_2 = \frac{D_2 L_a}{200} \qquad (2)$$

where D_1 = degree of curvature of flatter circular arc, degrees;
where D_2 = degree of curvature of sharper circular arc, degrees;
where L_a = length of combining spiral, feet.

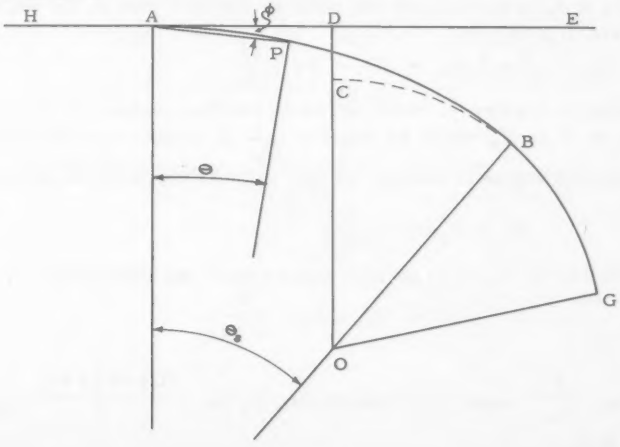

FIGURE 1

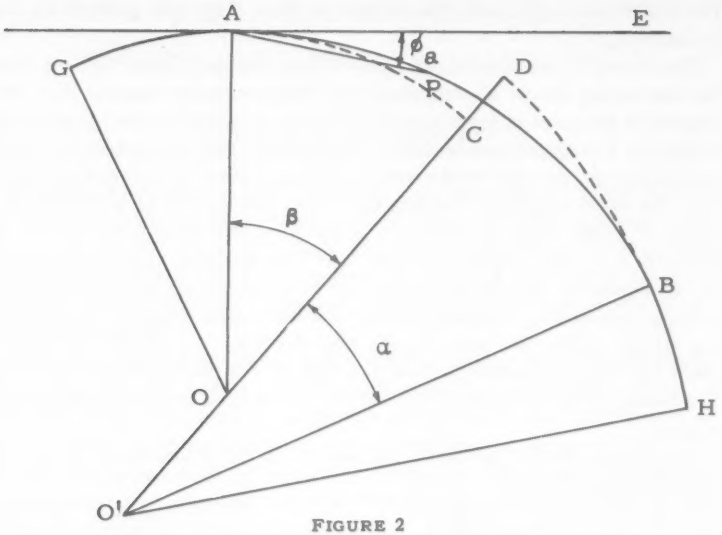

FIGURE 2

The theory also assumes that the offset p_a of the combining spiral is equal to the offset p of an equivalent simple spiral. The equivalent simple spiral is defined as one which has the same length and joins a tangent to a circular arc of degree $D_2 - D_1$.

To test the theory, it is necessary to derive the equations of the combining spiral. Referring to FIGURE 2, the degree of the spiral varies from D_2 at A, to D_1 at B. At any point P, distant l from A, the degree of curvature, D_p, is

$$D_p = D_2 - (D_2 - D_1) \frac{l}{L_a} \tag{3}$$

Referring to FIGURE 4, which shows an enlarged portion of FIGURE 2, radius at P is R_p which is equal to $\frac{1}{D_p}$ if lengths are expressed in stations, and angles in radians, as they will be throughout the derivation. Then

$$dl = R_p d\theta = \frac{d\theta}{D_p} \tag{4}$$

Substituting for D_p its value from EQUATION 3 and integrating

$$\theta = D_2 l - (D_2 - D_1) \frac{l^2}{2L_a} \tag{5}$$

Letting $\frac{l}{L_a}$ equal k and substituting θ_a for $\frac{(D_2 - D_1) L_a}{2}$ and Δ_2 for $\frac{D_2 L_a}{2}$

$$\theta = 2\Delta_2 k - \theta_a k^2 \qquad (6)$$

Also

$$dy = dl \sin \theta \qquad (7)$$

and

$$dx = dl \cos \theta \qquad (8)$$

Substituting for sine and cosine the respective series expansions in θ and integrating

$$y = l(\Delta_2 k - \frac{1}{3}\theta_a k^2 - \frac{1}{3}\Delta_2^3 k^3 + \text{----}) \qquad (9)$$

and

$$x = l(1 - \frac{2}{3}\Delta_2^2 k^2 + \frac{1}{2}\Delta_2 \theta_a k^3 - \frac{1}{10}\theta_a^2 k^4 + \text{-----}) \qquad (10)$$

Dividing y by x,

$$\tan \phi_a = \Delta_2 k - \frac{1}{3}\theta_a k^2 + \frac{1}{3}\Delta_2^3 k^3 - \text{---} \qquad (11)$$

Substituting $\tan \phi_a$ in

$$\phi_a = \tan \phi_a + \frac{1}{3}\tan^3 \phi_a + \frac{1}{5}\tan^5 \phi_a + \text{----} \qquad (12)$$

yields

$$\phi_a = \Delta_2 k - \frac{1}{3}\theta_a k^2 + \frac{1}{90}\Delta_2^2 \theta_a k^4 - \frac{1}{90}\Delta_2 \theta_a^2 k^5 + \text{----} \qquad (13)$$

The first term on the right is the deflection angle to the osculating circle. The second term on the right is ϕ. Actually

$$\phi = \frac{1}{3}\theta_a k^2 - \frac{8}{2835}\theta_a^3 k^6 - \frac{32}{467{,}775}\theta_a^5 k^{10} - \text{----} \qquad (14)$$

but it is more convenient to assume that ϕ is directly proportional to k^2 and include the remaining terms, all of which appear in EQUATIONS 13 and 14, in a single correction, C_a, to be applied to the nominal deflection angle.

$$C_a = \frac{1}{90}\Delta_2 \theta_a k^4(\Delta_2 - \theta_a k) + \frac{8}{2835}\theta_a^3 k^6 + \frac{32}{467{,}775}\theta_a^5 k^{10} \qquad (15)$$

$$+ \frac{1}{945}\Delta_2^3 \theta_a k^6(\Delta_2 - 2\theta_a k) + \frac{1}{113{,}400}\Delta_2 \theta_a^3(181\Delta_2 - 61\theta_a k)k^8 - \text{---}$$

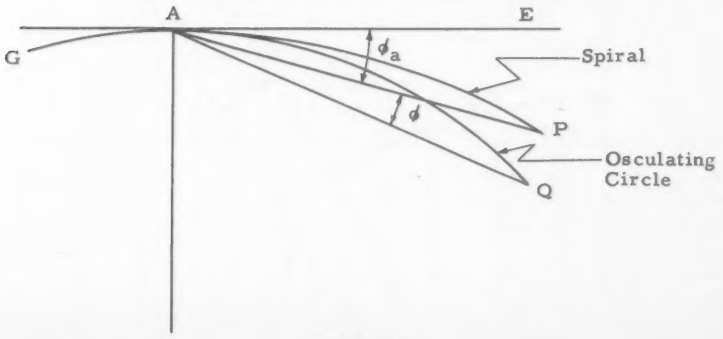

FIGURE 3

When the curvature of the spiral is increasing in the direction of layout,

$$\phi_a = \Delta_1 k + \phi - C_a \qquad (16)$$

and in the opposite direction,

$$\phi_a = \Delta_2 k - \phi + C_a \qquad (17)$$

The equation for C_a is too cumbersome to have any practical use in the form shown in EQUATION 15. With k equal to unity, the graph of FIGURE 6 may be constructed to give values of C_a with Δ_2 and θ_a as arguments. Such values of C_a apply only to the deflection angle to the end of a combining spiral from a setup at the beginning of the combining spiral.

To determine values of C_a for intermediate points on the spiral, it is necessary to consider an abbreviated spiral running from the point of setup to the sighted point only. Values of the arguments, Δ_2 and θ_a, for these abbreviated spirals are readily computed in tabular form as shown in TABLE 1. Here the computation of deflection angles is shown for a 400-foot combining spiral running from a 20° to a 10° circular curve. The point of setup is assumed at station 10 + 00 on the 20° curve. Notes run up the page to conform with field practice.

The tenth points of the spiral are to be established. Column 1 lists the

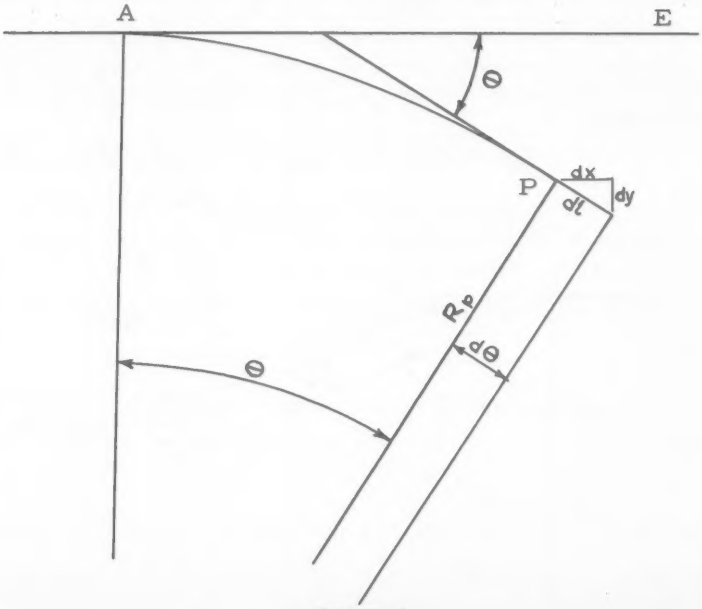

FIGURE 4

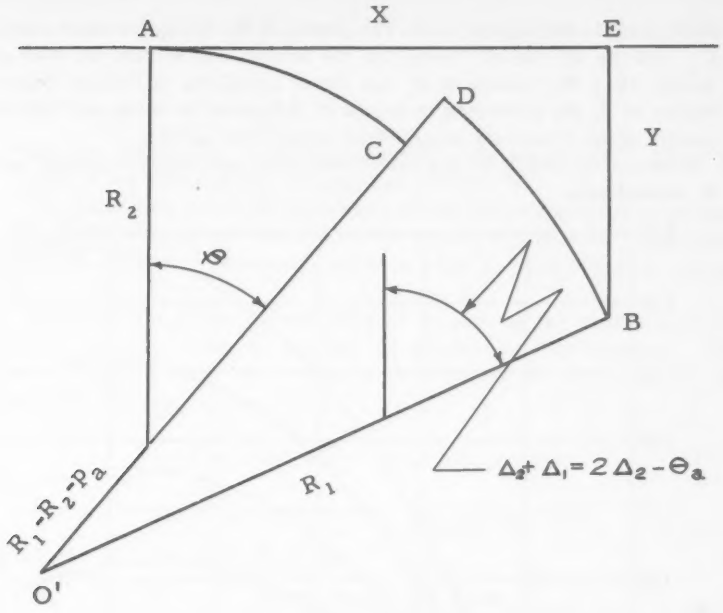

FIGURE 5

stationing; column 2 lists the osculating circle deflection; and column 3 the values of ϕ, the deflection angles to the tenth points of an equivalent simple spiral.

To use the graph of FIGURE 6, it is necessary to compute the values of Δ_2 and θ_a for the abbreviated spirals, *i.e.*, spirals running from the

TABLE 1

DEFLECTION ANGLES FOR 400-FOOT SPIRAL WITH $D_1 = 10^\circ$ AND $D_2 = 20^\circ$. SETUP AT STATION 10+00 ON 20° CURVE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Station	Oscul. circle	ϕ	Intermediate values							
	° ′	° ′	D_2 °	D °	L_a	Δ_2 °	θ_a °	C_a ″	(2) - (3) ° ′	(9) + (10) ° ′ ″
14+00	40-00	6-40	20	10	400	40	20.0	225	33-20	33-23-45
+60	36-00	5-24	20	9	360	36	16.2	157	30-36	30-38-37
13+20	32-00	4-16	20	8	320	32	12.8	104	27-44	27-45-44
+80	28-00	3-16	20	7	280	28	9.8	65	24-44	24-45-05
+40	24-00	2-24	20	6	240	24	7.2	36	21-36	21-36-36
12+00	20-00	1-40	20	5	200	20	5.0	19	18-20	18-20-19
+60	16-00	1-04	20	4	160	16	3.2	8	14-56	14-56-08
11+20	12-00	0-36	20	3	120	12	1.8	3	11-24	11-24-03
+80	8-00	0-16	20	2	80	8	0.8	1	7-44	7-44-01
+40	4-00	0-04	20	1	40	4	0.2	0	3-56	3-56-00
10+00										

setup point to the sighted point. The degree of the sharper circular curve, D_2, will be 20° in all cases, as the abbreviated spirals all start at station 10 + 00. Values of D_2 are listed in column 4. Column 5 lists values of D, the difference in degree of the spiral at setup and sighted point. Column 6 lists the length of the abbreviated spirals.

Values of Δ_2 and θ_a for the abbreviated spiral are listed in columns 7 and 8, respectively.

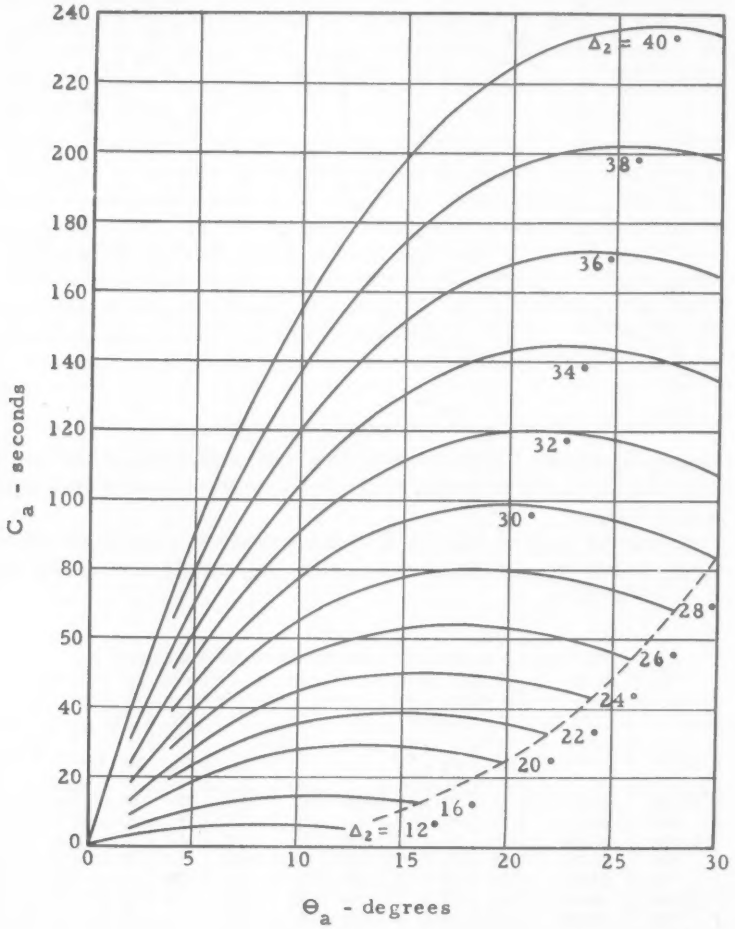

FIGURE 6. Correction, C_a, to be added to nominal deflection angle when spiral layout is in direction of decreasing curvature and subtracted when spiral layout is in direction of increasing curvature.

$$\Delta_2 = \frac{D_2 L_a}{200}$$

and

$$\theta_a = \frac{DL_a}{200}$$

Using the values of Δ_2 and θ_a as arguments, the values of C_a, listed in column 9, are obtained from the graph of FIGURE 6.

The deflection angles by osculating circle theory are listed in column 10, which is equal to column 2 minus column 3. The exact deflection angles are listed in column 11, which is equal to column 9 plus column 10.

Equations for β and p_a are obtained by solving the closed polygon shown by heavy lines in FIGURE 5. Solution is "by traverse," the direction of *OA* being assumed as north. Equating the summation of the latitudes and departures to zero,

$$R_2 - Y - R_1 \cos(2\Delta_2 - \theta_a) + (R_1 - R_2 - p_a)\cos\beta = 0 \qquad (18)$$

and

$$X - R_1 \sin(2\Delta_2 - \theta_a) + (R_1 - R_2 - p_a)\sin\beta = 0 \qquad (19)$$

Solving EQUATIONS 18 and 19 for β

$$\cos\beta = \frac{Y + R_1 \cos(2\Delta_2 - \theta_a) - R_2}{R_1 - R_2 - p_a} \qquad (20)$$

and

$$\sin\beta = \frac{R_1 \sin(2\Delta_2 - \theta_a) - X}{R_1 - R_2 - p_a} \qquad (21)$$

Dividing EQUATION 21 by EQUATION 20 to eliminate p_a,

$$\tan\beta = \frac{R_1 \sin(2\Delta_2 - \theta_a) - X}{Y + R_1 \cos(2\Delta_2 - \theta_a) - R_2} \qquad (22)$$

All terms on the right may be expressed in terms of Δ_2 and θ_a. Division yields

$$\tan\beta = \Delta_2 + \frac{1}{3}\Delta_2^3 + \frac{1}{30}\Delta_2^2\theta_a - \frac{1}{30}\Delta_2\theta_a^2 + \cdots \qquad (23)$$

from which

$$\beta = \Delta_2 + \frac{1}{30}\Delta_2^2\theta_a - \frac{1}{30}\Delta_2\theta_a^2 + \frac{1}{315}\Delta_2^4\theta_a - \frac{2}{315}\Delta_2^3\theta_a^2 + \frac{17}{7560}\Delta_2^2\theta_a^3 + \frac{1}{1080}\Delta_2\theta_a^4 - \cdots \qquad (24)$$

Δ_2 is the value of the central angle according to the theory. The remaining terms comprise a correction which may be determined from the graph of FIGURE 7. The correction must be added to Δ_2 to obtain β and subtracted from Δ_1 to obtain α.

With β known, either EQUATION 20 or 21 may be used to solve for p_a. Using EQUATION 21

$$p_a = \frac{(R_1 - R_2)\sin\beta - R_1\sin(2\Delta_2 - \theta_a) + X}{\sin\beta} \qquad (25)$$

Expressing all terms on the right in terms of Δ_2 and θ_a, division yields

$$p_a = L_a\left[\frac{1}{12}\theta_a - \frac{1}{240}\Delta_2^2\theta_a + \frac{1}{240}\Delta_2\theta_a^2 - \frac{1}{336}\theta_a^3 \right. \qquad (26)$$

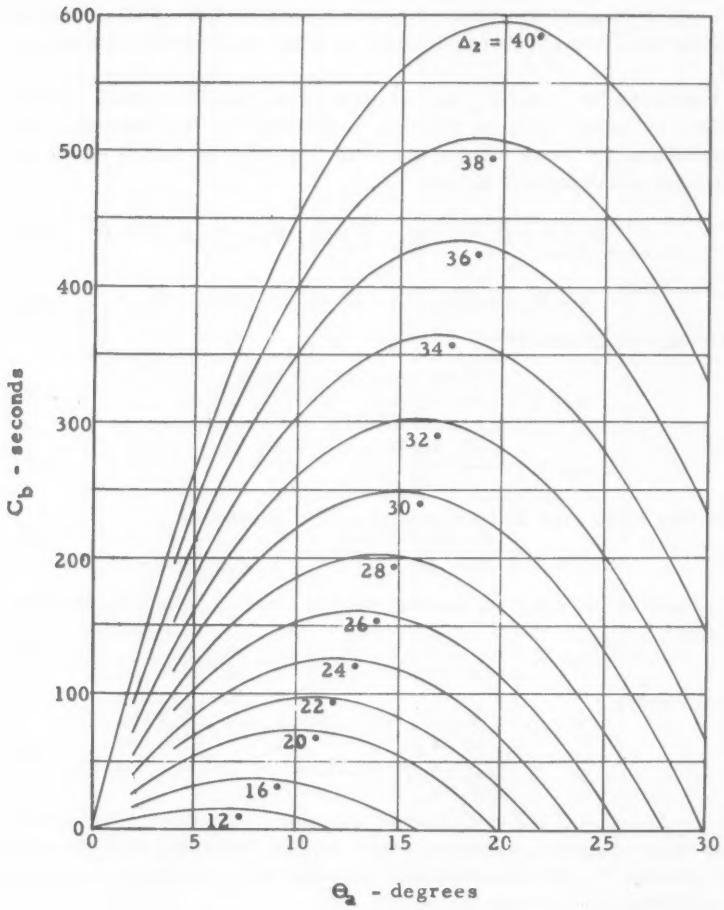

FIGURE 7. Correction, C_b, to be added to Δ_2 to obtain β.

$$+\frac{1}{10,080}\Delta_2^4\theta_a - \frac{1}{5,040}\Delta_2^3\theta_a^2 + \frac{1}{18,900}\Delta_2^2\theta_a^3 \qquad (26)$$

$$+\frac{1}{21,600}\Delta_2\theta_a^4 + \frac{1}{15,840}\theta_a^5 - - - - -\Big]$$

But

$$p = L_a\left[\frac{1}{12}\theta_a - \frac{1}{336}\theta_a^3 + \frac{1}{15,840}\theta_a^5 - - - - -\right] \qquad (27)$$

where L_a is the length of the equivalent simple spiral.

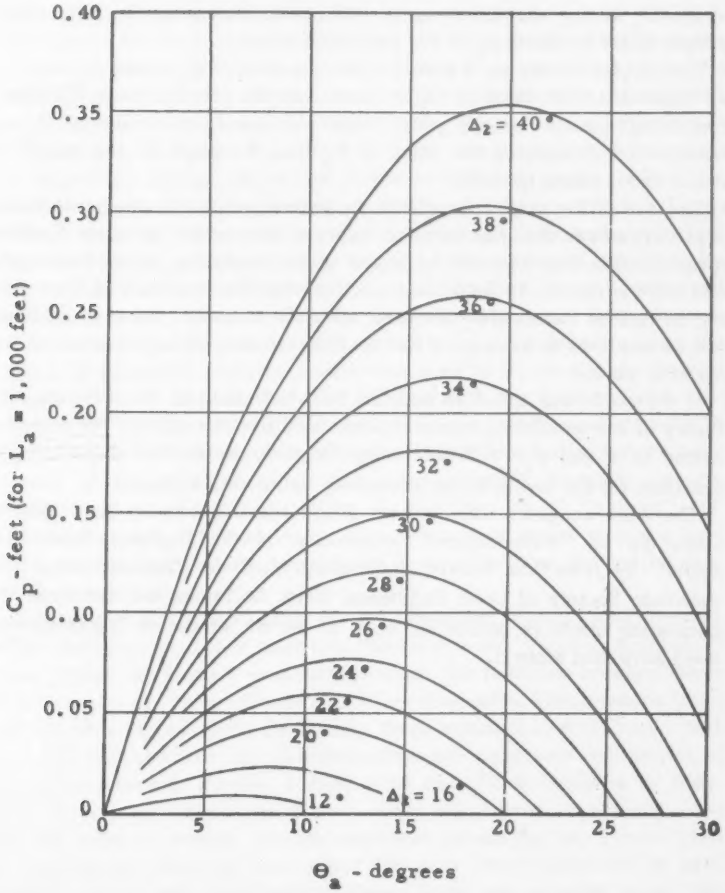

FIGURE 8. Correction, C_p for L_a = 1,000 feet, to be subtracted from p.

So,

$$p_a = p - L_a\left[\frac{1}{240}\Delta_2\theta_a(\Delta_2 - \theta_a) - \frac{1}{10{,}080}\Delta_2^4\theta_a + \frac{1}{5040}\Delta_2^3\theta_a^2 - \frac{1}{18{,}900}\Delta_2^2\theta_a^3 - \frac{1}{21{,}600}\Delta_2\theta_a^4 - \cdots\right] \quad (28)$$

Calling the bracketed terms C_p and ignoring all terms within the bracket after the first term because they are negligible for any practical highway spiral,

$$C_p = \frac{1}{240}\Delta_2\theta_a(\Delta_2 - \theta_a)L_a \quad (29)$$

where C_p is the correction to be subtracted from p of the equivalent simple spiral to obtain p_a of the combining spiral.

The graph of FIGURE 8 permits determination of C_p using Δ_2 and θ_a as arguments. The value of C_p obtained from the graph is for a 1000-foot combining spiral. For any other length of spiral, the value of C_p is obtained by multiplying the value of C_p from the graph by the length of spiral and dividing by 1000.

The use of the graphs simplifies the determination of corrections to be applied to values obtained from the theory of the osculating circle. Further simplification may be made by layout of the combining spiral from each end to the midpoint. Such a procedure eliminates the necessity of determining the various values of C_a because, up to the midpoint, these corrections are so small as to have no effect on the precision of layout required for highway work.

If the combining spiral is laid out from both ends to the midpoint, the theory of the osculating circle requires modification only in the determination of β and p_a. With this simplification, the method described is practical for the layout of any combining spiral on a highway.

The most complete bibliography of the spiral known to the writer is contained in "Mathematical Examination of the Highway Transition Spiral" by John Oran Eichler and Howard W. Eves, *Transactions of the American Society of Civil Engineers*, 1946. So far as the theory of the osculating circle is concerned, none of the 64 references listed therein does more than state it.

SECTION OF ANTHROPOLOGY

ON THE RELATION BETWEEN "CULTURE" AND "SOCIAL STRUCTURE"*

By Bernard Barber

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The subject of our discussion this evening is "On the relation between 'culture' and 'social structure'." At the very outset, I must ask your forbearance for my boldness in choosing so large and important a topic, a boldness all the greater in view of the scant time available to us. As you well know, there is already a considerable literature on this subject. I cannot claim to have mastered this literature, nor even to have read it all. However, the great importance for both anthropology and sociology as systematic disciplines of the problems involved in our subject has emboldened me to try my hand at it. Usage of the terms "culture" and "social structure" is commonly vague or confused in both anthropological and sociological writings. (For an encyclopedic survey of the diversity and confusion of meanings given to the term "culture," see Kroeber and Kluckhohn, 1952.) We need to make these terms not only more precise, but also more specific. The term "culture" is now too broad to carry the weight of scientific analysis usually assigned to it; so also is "social structure." Each term needs to be differentiated into finer analytic subcategories. This process of differentiation is a common phenomenon in the history of scientific concepts, and it is not improbable that we have arrived at the point where we can make scientific progress only by undertaking analytic differentiation of our concepts of "culture" and "social structure." Of course, we cannot settle all these problems here and now. But I hope I can provide, at least, the focus for fruitful discussion among us.

Toward this end, I shall adopt the following plan. First, I shall present some definitions of the concepts "culture" and "social structure." Then I shall state some propositions about the relations between these two concepts and the phenomena to which they refer. These propositions will contain the rationale for making these conceptual definitions, that is, they will indicate why the definitions are necessary and useful in empirical research. Finally, I shall give some brief examples to illustrate these propositions and show how our definitions are actually useful. In order to provide common empirical ground for us, I have tried to choose my examples from areas that have been discussed by both anthropologists and sociologists. These areas are: utopian ideas, the process of discovery and invention, and fashion in clothes.

*This paper was presented at a meeting of the Section on May 23, 1955.

Definitions

(1) The basic phenomena, or stuff, to which our definitions apply is what is variously called "human" or "social" or "cultural" behavior. Talcott Parsons has called this basic stuff "action." (My definitions are derived from and intended to follow the essentials of Parsons' definitions given in his *The Social System,* 1951.) "Action" phenomena are manifested primarily in the interaction of two or more individuals, and this interaction constitutes a "social system." "Action" phenomena are usefully conceived of as in a state of continual process. From this unending human process, we conceptually abstract two orders, or levels, or, best of all, kinds of data. One of these is repeated patterns of symbols or ideas. The other is uniformities and repeated patterns of interactional relationship. The repeated patterns of symbols or ideas we define as "culture." These symbols are shared, learned, and transmitted in and between the members of social systems. The uniformities and repeated patterns of interactional relationship we define as "social structure." (Of course, we also conceptually abstract a third kind of data from "action," namely, "personality" data. In this discussion, however, we shall ignore "personality" data, although they are always in interdependent interaction with "culture" and "social structure" in social systems.)

Culture, as a whole, is made up of several functionally different kinds of cultural data. For example, among the several kinds of patterned symbol- or idea-systems in the most inclusive kind of social system, namely, a "society," are the following: rational knowledge or science, language, logic, ideologies, values or norms, religious ideas, philosophical ideas, expressive symbols, and esthetic ideas. Each of these kinds of idea- or symbol-systems has its own function and its own principles of patterning. (See Parsons, *op. cit.*, esp. chaps. 3, 8 and 9, for an analysis of the functional necessity and principles of patterning of these different kinds of cultural data.)

Like culture, social structure as a whole is internally differentiated. Among the kinds of uniformities or repeated patterns of interactional relationship that we find in all of these social systems called "society" are the following: a kinship structure; a stratificational structure; an authority or power structure; a structure of property, exchange, and work relationships; a structure of socialization and educational relationships; an age and sex role structure; and a communications structure. Like culture, again, each component of social structure has its own functions, definite principles of patterning, and limited possibilities of variation. (See Murdock, 1949, for the best and most exhaustive analysis thus far made of the principles and limited possibilities of variation in kinship structure; see also, on social structural uniformities in kinship structure, the classic work of Radcliffe-Brown, 1952.) My two lists of

the cultural and social structural components of any society are not necessarily exhaustive and, certainly, they are not final. Many different lists of this kind have been made, with considerable overlapping among them. (For a list which is fairly similar to mine and which is explained in detail, see Aberle *et al.*, 1950.) The task of constructing a useful taxonomy of culture and social structure has been and must remain a continuing one at the center of social science theory.

Some Propositions About the Relations Between Culture and Social Structure

We can now state four generalized propositions about the relations between culture and social structure:

(1) Both culture and social structure are necessary functional components of any social system.

(2) Culture and social structure are, to some extent, independent of one another, that is, in part each is not determined by the other.

(3) Culture and social structure, however, are also to some extent interdependent with one another, that is, each sets some limits on the variability of the other.

(4) Each of the components within both culture and social structure is to some extent independent of, to some extent interdependent with, the other components, both in its own and in the other category.

In sum, any social system is the product of the several interdependent cultural and social structural components or variables relevant to it. Actual social systems are always compromises, so to speak, never the absolutely integrated or perfect realization of either culture or social structure.

Some Illustrative Examples

We may, finally, consider some brief empirical examples that illustrate one or more of the propositions we have stated about the relations between culture and social structure. Since our propositions apply in principle to any empirical action phenomena, it is obvious that a large number of examples would not only be possible but highly desirable. Even the examples I have selected can be examined only cursorily. I remind you that I have plunged into a very large subject with too little time to make myself as clear as I should like to be.

(1) Utopian ideas constitute our first example. I have stated above that ideologies are one invariant and functional cultural component of social systems. Ideologies are complexes of ideas that explain and justify the nature, present condition, and future course of a social system. Actual ideologies may consist of scientifically valid ideas, scientifically invalid ideas, and ideas that are not subject to scientific test. A particular ideology may have all these kinds of ideas intermixed. The

Marxian ideology is of this kind. One common kind of ideological idea is what we may call a "utopian" idea. A Utopian ideology is one that describes as a *possible* reality a social structural or cultural situation that is manifestly *impossible* of realization in social systems as anthropology or sociology now understand them to be constituted. For example, some utopian ideas are those that describe a society in which there is no family, or no class structure, or no property at all, or no political system, or no religion, or no values. Yet such ideas have existed in many societies, projecting into the future a "golden age," or a "kingdom of heaven on earth," or a communist society without classes, without property, without family, and without political authority. Moreover, utopian ideas of this kind persist despite contradictory ideas in the cultural realm of rational knowledge and science, and despite the resistance of social structure to their realization. These are examples of what is meant when we say that culture is to some extent independent of social structure and when we say that one cultural component is to some extent independent of other cultural components.

But such different components of social systems are also interdependent with one another. We can see this interdependence if we examine the history of the Union of Soviet Socialist Republics since its revolutionary origins. The Bolsheviks came to power armed with Marxian theory, a mélange of ideas that was in part utopian. Not only did they believe they could establish a classless society, but they thought the state, being merely a committee to advance the interests of the bourgeoisie, would wither away. They thought that the family too was a bourgeois superstition and thus would be unnecessary after the revolution. They felt they could do away with administrative differentiation and *expertise*. As Lenin put it, in communist society, any cook would be able to run the necessary administrative organizations. They thought that even in modern urban industrial societies the "backward" folk cultures of the ethnic and nationality minorities in the Soviet Union could be preserved unchanged. And so on went the ideological distortion of what the culture and social structure of communist society would be like. Because of the interdependence of ideology with other cultural and social structural requirements in society, however, the utopian ideologies could not be and have not been realized. We now possess an excellent body of social science literature that describes the actual course of Soviet history and shows how ideology has been checked by cultural and social structural necessity in nearly every area of Soviet society. (See Moore, 1950; Bauer, 1952; Berman, 1950; Inkeles, 1950; and Fainsod, 1953). Utopian ideology has only been checked, however, not eliminated. It persists as a strong influence on Soviet society, not only as a hope for the now indefinitely remote future, but also as a manifest influence on contemporary social processes. The ideology of a classless society has

not been realized, but it does provide a pressure that serves to keep the present class system as open as possible. If there is still a stratificational structure, then, so also is there probably more social mobility than there would be if the ideology did not affect men's behavior in Soviet society. It is a fact that even a utopian ideology can sometimes exist side by side with contradictory scientific ideas and have its independent, though limited influence on behavior. In the long run, however, it is likely that an ideology will give way before a scientific idea that genuinely invalidates it. But other ideologies, other utopias, will then take its place.

(2) The process of discovery and invention is our second illustration. The process of scientific and technological discovery, or indeed, of creative discovery in any cultural realm, whether literary, artistic, religious, or philosophical, is a complex social process involving the interaction of many cultural and social structural variables. This complexity and interaction have not always been recognized. For example, the common saw, "Necessity is the mother of invention," certainly fails to recognize the complexity, and perhaps also exaggerates the importance, of social structural variables. The Marxian view that the social relations of production determine the cultural "superstructure" of society seems also to give too much weight to social structural variables in the process of invention. On the other hand, the complexity and interaction in this process has sometimes been neglected by what we may call the "culturological" view, based on the recurrent phenomenon of independent multiple inventions of all kinds, that the cultural heritage simply spawns discoveries by some immanent process, in a kind of cultural parthenogenesis. There can be no question that certain prior scientific ideas are necessary conditions for any discovery. We see this clearly now in the attempt to discover the cause or causes of cancer. Still further, at any given point in the development and accumulation of ideas, the existing accumulation is one of the variables that determine foci of attention for pioneering and creative workers. But ideas, though necessary, are not sufficient. The process of invention, as I have tried to show in my book, *Science and the Social Order*, (Barber, 1952, esp. chaps. 2-4, 9), is not merely cultural, nor merely social, nor, for that matter, to mention another misconception, merely psychological, the product of individual genius alone. The rate, the type, and the very substance of scientific discovery are the product of the interaction of such cultural variables as religious and philosophical ideas, values, esthetic analogies, ideologies, and the existing scientific stock, on the one hand, and, on the other, of such social structural variables as the organization of university and other educational structures, the property system in ideas, the class structure, the structure of communication among scientists and between them and their several publics, the mode of organization

of industrial research laboratories and, I need hardly add, the political structure. All these cultural and social variables have been shown to make a difference for discovery and invention not only as between industrial and nonindustrial societies, but also as among different industrial societies, for example, among the United States or Nazi Germany or, at the present time, Soviet Russia. In sum, for the most empirical and fruitful research on this subject, experience shows that we need a conceptual apparatus that distinguishes culture from social structure, isolates the several component variables on these two levels, and assumes that each of these variables is at once independent of and interdependent with the others.

(3) Fashion in clothes is the last example to be mentioned in the space available. You know, of course, that I have chosen this subject because Kroeber has dealt with it intensively in a series of studies beginning in 1919. Kroeber and Jane Richardson, for example, have analyzed the stylistic changes in women's evening or formal dress for the period 1788-1936 (Richardson and Kroeber, 1940). They studied six kinds of patterned esthetic preferences in women's dresses, to wit: length of skirt, length of waist, depth of decolletage, width of skirt, width or thickness of waist, and width of decolletage. They found that "the basic dimensions of modern European dress alternate with fair regularity between maxima and minima which in most cases average about fifty years apart, so that the full wave-length of their periodicity is around a century."

This kind of study is, under my definition, entirely concerned with cultural data. The study demonstrates an element of independence in the principles of patterning of esthetic preferences in certain matters of the cut of women's clothes. So far so good. But the interdependence of cultural elements or styles with other cultural elements and with social structural variables is not taken up. For example, the cultural values and ideas that determine the maxima and minima of stylistic variation are not mentioned. With regard to length of skirt, for instance, norms concerning sexual propriety determine minimum length, and norms concerning efficiency determine maximum length. Further, the less work women's roles involve in a society, the longer and tighter skirts can be. Therefore, upper class women can adopt more easily than lower class women a stylistic fashion of long and tight skirts. So also, the long gown of the Chinese mandarin was a possible style only for the gentleman of leisure and not for the working peasant, who comprised at least 80 per cent of classical Chinese society. Thus, the structure of sex and social class roles, to mention only these two for the moment, is interdependent with the purely cultural stylistic element.

In a study of fashion in American women's clothes since 1930, Lobel and I have shown the interdependence of a whole series of cultural

and social structural variables. (Barber and Lobel, 1952.) I shall give you merely the gist of our study. One of the reasons that there is mass consumption and considerable changeability in American women's fashions is that our economic structure in general, and the structure of the dress industry in particular, are functionally related to a system of mass production. In comparison, more individualized consumption in France is functionally related to a more individualized production system, one that, from our point of view, is relatively inefficient. The fashion system in the United States is also interdependent with the social class structure. New fashions are usually taken up at or near the top of that structure and trickle down through all the strata. When they reach the bottom, the process begins all over again, with a new fashion that is symbolic of upper-class position. What trickles down, however, is not unchanged. Each class level defines what is appropriate somewhat differently. The "high-style" fashions suitable at the top are not suitable for middle-class, housewifely, PTA-ing, church-going women. Even at the top of the class system, there are differences of fashion, notably as between the more cosmopolitan group that adopts "high-style" Parisian modes and the more conservative, older-stock, Anglophile group that looks for fashion leadership to the more tailored styles of Best & Co. or Peck & Peck in New York, N. Y. Fashion is also modified, we found, by the structure of age groupings. The colors, stuffs, and cuts, for example, the decolletage, that are suitable for mature women are not always considered "decent" for unmarried adolescents, whose styles are supposed to be "pretty" rather than "fashionable." And the "casual" styles of college girls are different from those of other teenagers. The American fashion system is also interdependent with the American communications structure. Mass production and mass consumption require mass media of communication in this area as in so many others. Finally, perhaps it need hardly be mentioned that fashions in American women's clothes are influenced by scientific and technological discoveries, especially with regard to new materials and methods that make mass production and mass consumption continually feasible. In sum, Lobel and I found that the fashion system in American society is the product of several interdependent cultural and social structural variables.

In conclusion, may I be painfully repetitive and remind you how few examples we have had space for? We could have taken kinship behavior as an example and discussed in detail the social structural uniformities cutting across cultural differences that Murdock and Radcliffe-Brown have so brilliantly delineated. Or, to turn about, we could have discussed the influence of cultural variables such as values and ideologies on a social structural uniformity such as the isolated nuclear family in contemporary France, Germany, and the United States. Or, we could

have discussed the generic problem of the relation between kinship terminology as culture and actual kinship behavior as the product of both terminology and social structural requirements. Not all individuals in a kinship system called by the same kinship term interact with ego in the same way. Empirical examples from other areas of behavior also could have been used to illustrate the usefulness of my definitions. Perhaps we have had space at least for enough examples to suggest the necessity for theoretical clarification of the relations between culture and social structure. Perhaps we have even said enough to recommend to you, as a starting point in such clarification, the particular formulation I have put before you in this paper.

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SECTION OF OCEANOGRAPHY AND METEOROLOGY

A WEATHER CONTROL EXPERIMENT IN THE EASTERN UNITED STATES*

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The subject of artificial weather modification by cloud seeding has been a controversial one since 1946, when Doctors Schaefer, Vonnegut, and Langmuir first began their experiments with dry ice and silver iodide at the General Electric Research Laboratories in Schenectady, N. Y. Despite the large number of cloud-seeding experiments which have been conducted, opinions about the effects of seeding still run the gamut from "no effects whatsoever" to "widespread weather modification." Among other things, it has been suggested that the seeding of clouds with nucleating agents may have important effects not only on rainfall, but also on the development of cyclonic storms through the release of latent heat. The implications of this hypothesis are vast. In order to test it, a research project, Project SCUD, was established at New York University, New York, N. Y., in May 1952, under the sponsorship of the United States Office of Naval Research "to determine the effects of artificial cloud nucleation on cyclogenesis off the east coast of the United States." Although Project SCUD was originally classified as confidential, the scientific results were declassified in March 1955.

Design of the Experiment

Project SCUD was conducted in the east coastal region of the United States during two winter seasons, January-April 1953 and December 1953-April 1954. The design of the experiment and the statistical procedures used for the evaluation were established prior to the seeding in order to insure complete objectivity both in the conduct of the experiment and in its analysis. The elements of the experimental design are outlined below.

(1) *Selection of experimental units.* The weather situations selected for the experiment were cases of "possible" cyclogenesis in the east coastal region of the United States. Since one of the necessary conditions for east coastal cyclogenesis appears to be the existence of southerly tropospheric winds, seeding was limited to the region between the upper air ridge and the next trough to the west. This procedure introduced an element of homogeneity into the experiment and also

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provided a natural basis for the separation of cases. Only one case was selected in advance of each trough. Both the approaching trough and the next ridge to the west of the trough had to pass through the region before the following case was selected. Thus the experimental units were well separated from each other.

The experimental units were defined by a "zero hour," the time of beginning of seeding. Zero hour was selected on the basis of subjective forecasts of cloud structures and secondary cyclone development, as well as the upper air circulation. In the ideal case, a new secondary cyclone would be forming at zero hour somewhere in the east coastal region, and this development would be associated with extensive masses of supercooled cloud. Of course, few cases were ideal, and cyclogenesis, while "possible," did not always materialize.

(2) *The treatments.* The seeding materials included both silver iodide released from the ground and dry ice released from airplanes.

Seventeen silver iodide smoke generators (purchased from a commercial cloud-seeding company in California) were installed at 17 United States Navy and Coast Guard stations between Florida and New York. A 4 per cent solution of silver iodide in acetone was vaporized in a propane gas flame to produce the silver iodide nuclei. Each generator consumed one quart of solution per hour and all generators operated continuously for 12 hours, beginning at zero hour in each seeded case.

The dry ice was crushed into pellets about one quarter to one half inch in diameter and stored on the airplanes in insulated containers. (The airplanes and crews were provided by the Navy.) Over the target region, the dry ice was dispensed by means of a motor-driven feeder mechanism.

In the January-April 1953 season, the target regions were tracks about 1000 miles long, selected in each case by the forecasters at New York University. Three airplanes, each carrying 1000 pounds of dry ice, and flying approximately parallel tracks about 100 miles apart, dispensed one pound of dry ice per mile until the supply was exhausted, or until seedable clouds were no longer available. Flight altitudes ranged from 10,000 to 15,000 feet above sea level. Seeding began at, or shortly after, zero hour.

In the December 1953-April 1954 season, the target region was one of six overlapping target areas into which the east coastal region was divided. Each target area covered approximately 70,000 square miles. Three standard tracks, each about 500 miles long, were established in each target area. In this season, each of the three airplanes carried 2500 pounds of dry ice and dispensed it at the rate of five pounds per mile. Flight altitudes ranged from 15,000 to 25,000 feet above sea level. The target areas were selected to coincide with the region of expected cyclogenesis and/or maximum cloud development.

(3) *Randomization and controls.* Half of the selected cases were set aside to be used as a control group. These unseeded cases were chosen "at random" to eliminate bias.

The randomization was performed in consecutive pairs by a multiple coin-tossing procedure. If the first case of a pair was selected by the coin toss as a seeded case, the second member of that pair was left unseeded, and vice versa.

The experimental units (cases) were selected by the project staff at New York University. The random arrangement of these units into seeded and unseeded cases was carried out, however, by the Navy Project Officer in Norfolk, Va., who also transmitted the seeding instructions to the 17 silver iodide generator operators and to the Navy airplane squadron in Jacksonville, Fla. The information telling which cases were seeded and which were not was withheld from the New York University group until the end of the experiment so that there would be no bias in the selection of cases.

In the unseeded cases, one airplane was dispatched over the selected track, or target area, to obtain data (cloud tops, cloud temperatures, cloud photographs) which were used in the comparison of the control and seeded groups.

(4) *Test variates.* The selection of test variates for the evaluation of the experiment was, of necessity, rather arbitrary. There were many physical quantities to choose from and many periods and regions over which these quantities could be measured. Some experimenters in cloud seeding believe one should look only for very local effects (*e.g.*, cloud modification). Others believe precipitation may be affected perhaps 100 miles downwind. And still others are of the opinion that seeding may produce world-wide changes in rainfall and circulation patterns.

The variates selected for this experiment were "large-scale" quantities in the sense that they were measured over time and space intervals commensurate with the size, speed, and duration of extratropical cyclones. The seven test variates used are listed below.

(a) R1: The average 24-hour precipitation (inches) in the east coastal region beginning at zero hour. This region of the United States, which was precisely defined, lies approximately east of the Appalachian Mountains between latitudes 30 and 45 degrees north. It includes portions or all of the Atlantic coastal states as well as Vermont and eastern Pennsylvania. The average precipitation was obtained from a uniform distribution of 270 United States Weather Bureau raingauge stations (approximately one station in 800 square miles).

(b) R2: The average 24-hour precipitation (inches) in northern Maine, in the Canadian Maritime Provinces, in Newfoundland, in southeastern Quebec, and in southern Labrador beginning 12 hours after zero hour. R2 was selected as a measure of a possible delayed, downstream effect of seeding.

(c) Rt: The average 24-hour precipitation (inches) in the target area beginning at zero hour. This measure of the "local" effect of dry-ice seeding was applied only to the data from the second season.

(d) P1: The average 24-hour sea-level pressure change (millibars) beginning at zero hour in the east coastal region and adjacent ocean area. This region, extending to latitude 46 degrees north, longitude 57 degrees west in the northeast, and 30 degrees north, 69 degrees west in the southeast, was used to measure the short-period effect of seeding on cyclone development, as reflected in the pressure-change field.

(e) Pm1: The maximum 24-hour decrease of sea level pressure (millibars) beginning at zero hour in the region described above.

(f) P2: The average 24-hour sea-level pressure change (millibars) beginning 12 hours after zero hour in the southeastern Canadian and adjacent ocean area. At latitude 35 degrees north, the southern boundary, this region extends from longitude 70 degrees west to 54 degrees west. On the northern boundary, latitude 55 degrees north, the region extends from longitude 70 degrees west to 46 degrees west. This region was used to determine the delayed, downstream effect of seeding on cyclone development.

(g) Pm2: The maximum 24-hour decrease of sea-level pressure (millibars), beginning 12 hours after zero hour in the region described above.

TABLE 1

MEANS AND 95% CONFIDENCE LIMITS FOR ALL TEST VARIATES. PROJECT SCUD. JANUARY-APRIL 1953, DECEMBER 1953-APRIL 1954.

Variate		*Seeded (S)*	*Control (C)*	*No. Cases*
R1 (inches)	Observed arithmetic mean	0.322	0.305	37
	Observed geometric mean	0.224	0.229	36
	Adjusted geometric mean	0.220	0.233	36
	Confidence limits	0.66< S/C <	1.35	36
R2 (inches)	Observed arithmetic mean	0.184	0.174	37
	Observed geometric mean	0.088	0.107	36
	Adjusted geometric mean	0.079	0.118	36
	Confidence limits	0.32< S/C <	1.39	36
Rt (inches)	Observed arithmetic mean	0.414	0.365	16
	Observed geometric mean	0.217	0.278	16
	Adjusted geometric mean	0.225	0.268	16
	Confidence limits	0.20< S/C <	3.52	16
P1 (mb)	Observed mean	−4.11	−4.87	37
	Adjusted mean	−3.65	−5.30	36
	Confidence limits	−2.55<(S−C)<	5.85	36
Pm1 (mb)	Observed mean	−19.30	−19.31	37
	Adjusted mean	−19.61	−19.31	36
	Confidence limits	− 5.37<(S−C)<	4.94	36
P2 (mb)	Observed mean	− 5.18	− 6.27	37
	Adjusted mean	− 5.87	− 5.71	36
	Confidence limits	− 5.21<(S−C)<	4.89	36
Pm2 (mb)	Observed mean	−22.98	−22.48	37
	Adjusted mean	−23.33	−22.60	36
	Confidence limits	− 4.80<(S−C)<	3.34	36

(5) *Method of analysis.* The data collected were analyzed by the method of analysis of covariance for a randomized blocks design. (This method is described in various textbooks on statistical methods and design of experiments.)

The analysis of covariance enables us to compare the sample means of the test variates for the seeded cases with those for the control cases by first adjusting the original data for nontreatment effects which may be attributed to regression on one or more covariates. After the sample means have been adjusted, the variability of the individual values is taken into account in the calculation of confidence limits for the differences of the "true" adjusted means.

The adjustments for covariates not only reduce nontreatment differences between the sample means which the randomization has not completely eliminated, but also shrink the size of the confidence interval by reducing the residual variance.

The covariates used in the analysis were an index of the intensity of meridional circulation (M), a measure of the latitude of the cyclone or katallobaric center (L), and a measure of the convergence of water-vapor flux in the east coastal region up to 400 mb. (T). These covariates were measured at zero hour, or as close to zero hour as possible. In addition, the quantity P1 was used as a covariate for the analysis of P2, and Pm1 was used for the analysis of Pm2. The selection of the covariates was based on meteorological experience, physical reasoning, and some correlation analysis conducted prior to the experiment.

Statistical Results

At the outset, there was little expectation that a subjective, synoptic analysis of the data would provide much useful information regarding the effect of seeding. This proved to be the case. The synoptic analysis showed that the complexity and variety of weather situations was such that no meteorologist could state with any certainty that seeding had or had not caused this or that effect. This inconclusiveness was made very obvious by the use of randomization. There were certainly no startling differences between the composite synoptic analyses of the seeded and control cases.

The statistical results of the experiment are contained in TABLE 1. Logarithms and geometric means have been used in the analysis of the precipitation on the assumption that the effect of seeding should be proportional to the precipitation itself. Thus, the confidence limits for precipitation are computed for the ratio of seeded to control precipitation. The arithmetic means, however, are also included in the table.

The observed arithmetic means have been calculated on the basis of 37 cases, 19 of which were seeded and 18 of which were not. The adjusted means and confidence limits, however, have been computed for 36 cases,

the one incomplete block having been eliminated. Ninety-five per cent confidence limits have been used throughout.

The statistical analysis was carried out by the Analytical Research Group at Princeton University, Princeton, N. J.

As the lengths of the confidence intervals indicate, the precision of the experiment was not as great as we would have liked it to be. Still, it is possible to state some conclusions from the statistical analysis.

First, there is no evidence in any of the variates that the seeded and control samples were drawn from different populations. None of the differences between the sample means were found to be statistically significant.

Adjusted precipitation in the east coast region was about 5 per cent higher in the control sample than in the seeded sample, with only about one chance in 20 that seeding either increased or decreased precipitation more than about 35 per cent.

In southeastern Canada, adjusted precipitation was 40 per cent higher in the control sample. But the variance was such that we can say only that there is not more than one chance in 20 that the true ratio of seeded to control precipitation lies outside the interval between 32 per cent and 139 per cent.

The target area precipitation contains very little information due to the small number of cases and the large variance.

The differences between the sample means of the pressure variates were uniformly small. The means of the maximum pressure changes were, in fact, almost identical. The average value of the maximum pressure change was about –20 mb. with only about one chance in 20 that the difference between means of the control and seeded samples exceeded ± 5 mb.

If seeding had any effect on the large scale precipitation or on the pressure field, it was too small to be detected against the background of natural meteorological variance.

DIVISION OF MYCOLOGY

HETEROKARYOSIS AND SEXUALITY IN FUNGI*

By John R. Raper

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Heterokaryosis, the association of genetically diverse nuclei in a system capable of propagation, is a phenomenon peculiar to, but common in, the fungi. During the brief period of two decades, this unique function has been revealed as a major contributing factor to the remarkable adaptive capacity and to the high degree of variability commonly encountered among the members of this group. The biological utility of heterokaryosis is exemplified by its role in three phenomena of profound biological significance: it is the basis for a quickly attained adaptive variation tailored to meet specific situations—the "dual phenomenon" of Hansen;[1] it provides a mechanism for the restoration of normal function in combined, separately deficient, genomes;[2,3] and it has probably served as the chief vehicle for the evolution of the highly efficient patterns of sexuality characteristic of the higher fungi.[4]

The role of heterokaryosis in the evolution of such highly evolved patterns of sexuality as multiple-allelomorph heterothallism in the Basidiomycetes, however, represents only one aspect of a dual capacity to effect long-range alterations in sexuality. The opposed role of the gradual replacement of true sexual processes has been, unquestionably, of equal importance in the evolution of the very numerous species of fungi (20 per cent of all fungal species, according to Bessey[5]) that are devoid of sexuality. In addition to these two antithetical situations, which may be considered as terminal effects, there exist many intermediate and fluid relationships between heterokaryosis and sexuality. It is the purpose of this account to explore briefly the over-all relationship between heterokaryosis and sexuality in fungi.

As regards sexuality, three major distinct habits can be recognized among the fungi: (1) strictly asexual forms in which no changes in nuclear phase are imposed by cyclic nuclear fusions and reductions; (2) sexual forms in which homokaryotic individuals are routinely self-fertile; and (3) sexual forms in which obligatory cross-mating between homokaryotic individuals is genetically imposed.** Such obligatory cross-mating is imposed by a number of distinct genetic devices in the various groups of the fungi. These devices have been discussed elsewhere in some detail,[6] and are as follows: (1) single alternate sexual factors; (2) multiple alternate sexual factors; (3) hermaphroditism with incom-

*This paper, illustrated with lantern slides, was presented at a meeting of the Division on May 27, 1955.

**Categories (2) and (3), as thus defined, closely parallel homothallism and heterothallism, as commonly construed. There are minor deviations, however, as in phenotypically determined heterothallism, and as in secondary homothallism.

patibility factors* at a single locus; (4) alternate sexual factors with incompatibility factors at a single locus; (5) one pair of incompatibility factors at a single locus in the absence of any sexual differentiation; (6) multiple incompatibility factors at a single locus (*bipolar*); and (7) multiple incompatibility factors at each of two loci (*tetrapolar*).

Heterokaryosis occurs regularly in species exhibiting the latter five of these basic patterns of sexuality, as well as in numerous self-fertile forms and in most sexually sterile species. The heterokaryons that occur under these diverse conditions of sexuality, however, are at least as divergent as the patterns of sexuality with which they are associated. Numerous bases for variability among heterokaryons can be illustrated best by a brief characterization of heterokaryons in general.

Heterokaryosis is of common though not universal occurrence among the fungi. In the Phycomycetes it is very rare, and its occurrence in the more primitive Ascomycetes, the Hemiascomycetes, is doubtful. In all higher fungi, *e.g.*, in the more advanced Ascomycetes, throughout the Basidiomycetes, and among the Fungi Imperfecti, heterokaryosis is extremely common, and may well be a universal attribute of these groups.

Heterokaryons may originate in various ways, of which two are common and typical:

(1) Hyphal fusions between genetically dissimilar individuals establish heterokaryotic associations which can be extended tremendously through growth of the cell containing the originally associated nuclei or through the migration of their daughter nuclei into pre-existing homokaryotic elements.[7,8,9]

(2) Genetically dissimilar nuclei may occur in the same spore as the result of the regular production of binucleate spores in "secondary homothallic" species,[10,11,12] abnormal cleavage in species normally producing uninucleate spores,[13,14] or random cleavage following multiple fusion and meiosis in a germ sporangium.[15,16] Following either of these events, the bi- or multinucleate spore develops directly into a heterokaryon upon germination.

Most heterokaryotic associations, of whatever origin, provide far-reaching benefits to the species in which they occur. These benefits follow directly from a single characteristic common to a vast majority of all heterokaryons. This characteristic is that any genetic inadequacy of either component strain is masked by the corresponding normal capacity of the other. This interaction, known as complementation and common between the more closely associated genomes of higher, diploid forms, applies to various kinds of genetic deficiencies, *e.g.*, synthetic activities producing essential protoplasmic constituents,[3,17,18] missing or mutated links in the chain of events determining normal form,[2,19] normal pig-

*Incompatibility may be defined as a genetic device that determines, by the interplay of nonsexual factors, the pattern of cross-mating between individuals of the same species.

mentation,[20,21,22] etc. Since complementation requires different genetic deficiencies in the two associated strains, heterokaryons have been widely used in biochemical genetics to test allelism,[3] a test that applies equally well to strictly asexual forms, where the usual genetic tests are inapplicable.

Thus heterokaryosis mimics, via complementation, one of the basic attributes of sexuality in diploid organisms. Because of the balanced complementation between the two associated genomes, an individual belonging to the diploid higher plants and animals can achieve a degree of perfection far beyond the genetic contribution of either parent. Heterokaryosis, moreover, provides essentially the same benefits in a system capable of greater expedience and greater flexibility than provided by routine genetic reassortment via true sexuality, since the association can be formed immediately upon contact of the two component strains, and its relative lability permits subsequent readjustments to its immediate environment.

The number of participants in a heterokaryotic association is usually two, but, in certain cases common among asexual forms, three, or occasionally more, genetically diverse types may be found in a single mycelium.

The extent of heterokaryosis between juxtaposed strains varies widely, and it depends upon the ability of each nuclear type to migrate into the pre-existing plant body of the mate, and upon the ability of the initiated heterokaryon to propagate itself in competition with the two homokaryotic originals. At the one extreme, heterokaryosis is limited to the immediate vicinity of the intermingled filaments of the two strains.[22,23] Such ordinarily restricted heterokaryons can sometimes be made to develop extensively if they are isolated,[17,23] or if they have a high preferential selective value.[18] At the other extreme, reciprocal nuclear migration from each mate, into and throughout the plant body of the other, rapidly converts both pre-existing homokaryotic mates into a single uniform heterokaryon,[9,24] or into two reciprocally constituted and distinct heterokaryons.[18] The extent of heterokaryosis, including expressions between these extremes as well as unilateral heterokaryotization, can be rationalized by the varying ability of the nuclei of each component strain to migrate and divide in the preformed cytoplasm of the other.[23,25]

Heterokaryons also differ widely in the degree of stability that they exhibit in vegetative growth and in asexual reproduction. In vegetative growth, heterokaryons vary from extreme stability on the one hand to extreme lability on the other. Most stabile of all heterokaryons is the dikaryon of the Basidiomycetes, from which the components can be recovered only by microsurgery,[26,27,28] or by the presence of certain bile salts in the medium.[29] In labile heterokaryons, individual filaments grow into purely homokaryotic sectors with great frequency.[23,30]

Asexual spore production inevitably sorts out the heterokaryotic components to a greater or lesser extent depending, primarily, upon the number of nuclei per spore. When uninucleate spores are formed, the heterokaryon is necessarily reduced to its component strains.[20,31] Such sorting out regularly occurs in many of the otherwise extremely stable dikaryons of the Basidiomycetes.[32,33] When multinucleate asexual spores are formed, a degree of heterokaryotic stability is provided, for, in a fraction of spores containing nuclei of both component types, the heterokaryotic association is preserved.[1,22] In heterokaryons terminating in completion of the sexual cycle, desirable combinations of characteristics may be stabilized by recombination, but there is no possibility of the persistence of the heterokaryon *per se*. This persistence may be achieved, in effect, however, by rare somatic diploidization in certain homothallic or sterile Ascomycetes,[34] a process termed *parasexuality*.[35]

In different heterokaryons, the ratio of nuclei of the two diverse types can vary from unity to such disparate values as 2000:1.[36,37,38] An immediate differentiation is possible between two types of heterokaryons: those with a fixed nuclear ration of 1:1, and those in which the ratio is indeterminate and variable with altered environmental conditions.

In the fixed ratio heterokaryon, the dikaryon, pairs of nuclei derived one from each original mate are early established. Synchronized, *conjugate division* subsequently maintains the ratio at exact equality.[36,37] The dikaryon is universally present in all higher fungi that reproduce sexually. In the Ascomycetes, it is restricted in growth and is parasitic on the vegetative mycelium. In the Basidiomycetes, it is capable of independent and indefinite vegetative growth.

In heterokaryons lacking the precise mechanism of conjugate division, the nuclear ratio varies widely,[30,38] both between heterokaryons and in a given heterokaryon under different conditions.[39] The determination of nuclear ratios is seldom ideally simple and direct, because of nonrandom distribution of nuclei in spores,[40] variation in the number of nuclei per spore,[41] and, in species lacking asexual spores, the necessity of fragmenting the mycelium, a process with a number of consequent uncertainties.[19]

In most indefinite ratio heterokaryons, as exemplified by balanced, nutritionally deficient heterokaryons, ratio determination and maintenance is thought to result from the preferential selection of those elements that were provided by chance with the particular mixture of nuclei permitting maximal growth or the maximal expression of normal characteristics.[3]

There are, however, exceptional cases, such as the common-A heterokaryon in tetrapolar species, where such balancing does not obtain.[18] Here, reciprocal nuclear migration rapidly converts two juxtaposed strains into heterokaryotic associations but, in each, the original

resident nuclear type retains its predominance and its numerical superiority in ratios ranging from slightly greater than 1:1 to values well in excess of 2000:1.[19] Thus, from the two interacting strains, two reciprocally constituted and distinct heterokaryons are routinely formed. Two features of this type of heterokaryon are noteworthy: (1) it is extremely stable, in spite of the marked minority of the nuclei of the secondary (invader) type and in spite of the absence of secondary nuclei in relatively large segments of its mycelium; and (2) there is no complementary masking of genetic deficiencies between predominant and secondary components.

Heterokaryons thus display a tremendous range of variability in respect to almost every criterion of comparison. An appreciable portion of this variability can be correlated with the various incompatibility mechanisms present in the higher fungi. Basically, five different major categories are determined by the specific combinations of incompatibility factors that may be brought together in the two component strains. These major categories of heterokaryons, discussed in some detail elsewhere,[18] are as follows:

Compatible. There are different factors at one locus (in forms with a unifactorial mechanism) or at two loci (bifactorial). Compatible interactions typically lead to the fixed-ratio heterokaryon, the dikaryon, and presage the completion of the sexual cycle. The indefinite ratio heterokaryons of certain Ascomycetes, in secondary homothallic and in heterothallic species, are notable exceptions.[2, 8, 14, 24, 42] It is noteworthy here that, in species having multiple allelic incompatibility mechanism, most interindividual encounters oppose compatible strains (up to > 98 per cent in the bipolar and tetrapolar Hymenomycetes[43]).

Hemicompatible-a and *hemicompatible-b.* There are, respectively, different factors at one incompatibility locus and identical factors at the other, interactions possible only in species with a bifactorial incompatibility mechanism (tetrapolar). These recently discovered heterokaryons[23] are still imperfectly characterized and are quite different from heterokaryons of all other types. Both types are commonly infertile, leading to no further development stage. Eventual fruit production in both common *A* and common *B* combinations, however, have been rarely reported.[44, 45]

Noncompatible. There are identical factors at one locus (unifactorial) or at two loci (bifactorial). Heterokaryons of this type are readily established and are of common occurrence among the Ascomycetes. Recent evidence indicates noncompatible heterokaryons in a tetrapolar Hymenomycete, but absolute proof of heterokaryosis is wanting.[18] Dikaryons have not been reported in any noncompatible combinations.

A-compatible. These are interactions between individuals of species lacking differentiative incompatibility mechanisms. Such species may be either homothallic or asexual. Interactions of this type resemble those of

the previous category in that no incompatibility differences exist between the two components, and the resulting heterokaryons are similar to those of the noncompatible type. Heterokaryosis here is all but wholly of the indefinite ratio type with two, or rarely more than two, components, although dikaryons must occasionally be implicated when cross-mating occurs between genetically dissimilar components.[17]

The distribution of heterokaryons of the various types differentiated by nuclear ratios and specific incompatibility-factor combinations is shown in relation to the major types of incompatibility mechanisms in FIGURE 1.

A final aspect of the relationship between heterokaryosis and sexuality in fungi concerns the correlation of the known occurrence of heterokaryons of the various types delineated above with the major phylogenetic groups in the fungi. A faltering step is made in this direction in FIGURE 2 where, upon a phylogenetic arrangement of the fungi (based on that of Gaumann[46]), are indicated the chief differentiative patterns of sexuality and the types of heterokaryons occurring in the several groups. Inadequate information about each of the three aspects compared here* permits only the recognition of broad correlative trends, but even a broad tentative integration can have the utility of stimulating more precise efforts and, even at this stage, the evolutionary significance of the evident broad trends is unmistakable.

(1) Sexual differentiation as a means to regulate cross-mating is largely confined to the more primitive groups.

(2) Incompatibility mechanisms of increasingly evolved complexity progressively supersede sexual differentiation.

(3) Heterokaryosis of one type or another is almost universally a concomitant of incompatibility mechanisms.

(4) Heterokaryosis, in the form of the dikaryon, becomes the main vehicle for sexual processes to the extent that the entire class of Basidiomycetes, with the exception of some members of a single group—the rusts—has achieved a completely sexual mode of reproduction without any sexual specialization whatever.

(5) Heterokaryosis, of the indefinite-ratio type, appears to have replaced sexuality and seems to act as an effective substitute for sexuality in the members of another large group, the Fungi Imperfecti, not included in FIGURE 2, but probably derived from the main sequence from the more primitive groups having an incompatibility mechanism.

Thus, through the interrelated systems of sexuality and heterokaryosis the fungi have achieved a degree of biological plasticity unknown elsewhere. Heterokaryosis, of many different types and of almost infinite

*For example: the general phylogenetic arrangement of Gaumann's is only one of several quite dissimilar but equally plausible schemes. It is uncertain whether the differentiative mechanism in the heterothallic Zygomycetes is based on sexual or incompatibility distinctions,[47] and whether certain smuts have 1-locus 2-allele, or 2-locus multiple-allele incompatibility.[48] The survey of the detailed characteristics of heterokaryons, except in a few scattered species, is woefully incomplete throughout.

	Homothallic and Asexual	Heterothallic		
Incompatibility Mechanism	None 0	1-locus-2-allele A, a	1-locus-∞-allele A^n	2-locus-∞-allele $A^n B^n$
Distribution	Phycomycetes Ascomycetes Imperfects	——Basidiomycetes——		
Type:				
A. Compatible	—	$(A+a)^{\|}$ $(A \neq a)^{\|}$	$(A^x + A^y)$	$(A^x B^x + A^y B^y)$
B. Hemi-compatible-a	—	—	—	$(A^x B^x \neq A^x B^y)$
C. Hemi-compatible-b	—	—	—	$(A^x B^x + A^y B^x)$ $(A^x B^x \neq A^y B^x)$
D. Non-compatible	—	$(A \neq A)(a \neq a)$	$(A^x \neq A^x)$	$(A^x B^x \neq A^x B^x)$
E. A-compatible	$(0+0)$ $(0 \neq 0)$ $(0 \neq 0 \neq 0)$	—	—	—

$^{|}+$ = Nuclear ratio 1:1, conjugate division
$\neq$ = Nuclear ratio indefinite

FIGURE 1. The incompatibility factor constitution of heterokaryons in relation to the major incompatibility mechanisms.

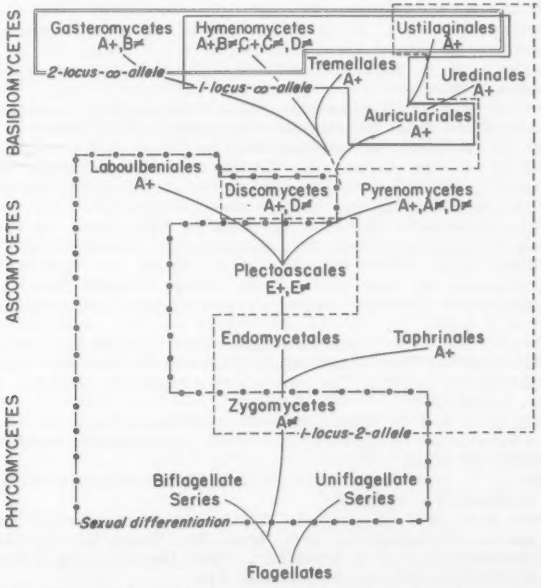

FIGURE 2. The relationship between heterokaryosis of the major types (*cf.* FIGURE 1), the various types of differentiative patterns of sexuality, and the broad phylogenetic progression in the fungi.

variability, acting sometimes as an accessory to and sometimes as a substitute for true sexual processes, greatly extends the possibilities for the effectiveness of genetic complementation and/or recombination. The highest possible degree of variability and adaptibility would be expected in a species in which any two individuals can interact immediately to pool their genetic resources in temporary or permanent associations. This goal would appear to have been effectively attained in many groups of the higher fungi.

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CONFERENCES HELD

SECTION OF BIOLOGY

AND

THE DAMON RUNYON MEMORIAL FUND FOR CANCER RESEARCH, INC

ASCITES TUMORS AS TOOLS IN QUANTITATIVE ONCOLOGY

Thursday, May 19 and
Friday, May 20, 1955

Conference Chairman: Theodore S. Hauschka
Roswell Park Memorial Institute, Buffalo, N. Y.

THURSDAY, MAY 19, 1955

GROWTH AND POPULATION ANALYSIS

Session Chairman: Austin Brues
Argonne National Laboratory, Lemont, Ill.

9:00 A.M. –
Introductory Remarks – Hilary Koprowski, Chairman, Section of Biology, The New York Academy of Sciences, New York, N. Y.; Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

"Conversion of Solid Neoplasms into Ascites Tumors" – G. Klein, Institute for Cell Research & Genetics, Karolinska Institutet, Stockholm, Sweden.

Discussion: J. Lederberg, University of Wisconsin, Madison, Wis.

"Growth of Cell Suspensions in Tissue Culture" – Wilton Earle, National Cancer Institute, Bethesda, Md.

Discussion: Robert Hull, Eli Lilly and Company, Indianapolis, Ind.

"Immunoselection of Polyploids from Predominantly Diploid Cell Populations" – Theodore S. Hauschka, Roswell Park Memorial Institute, Buffalo, N. Y.

Discussion: B. Amos, Guy's Hospital Medical School, London, England.

'Growth Characteristics of Free Tumor Cells in Various Body Fluids and

Tissues of the Mouse" – Horace Goldie, Meharry Medical College, Nashville, Tenn.

Discussion: George O. Gey, Johns Hopkins Medical School, Baltimore, Md.

"Measurement and Nature of Growth Curves of Ascites Tumors" – Harvey M. Patt, Argonne National Laboratory, Lemont, Ill.

Discussion: Oscar W. Richards, American Optical Company, Southbridge, Mass.

CYTOLOGIC MERITS OF ASCITES TUMORS

Session Chairman: Charles M. Pomerat
University of Texas–Medical Branch, Galveston, Texas

2:00 P.M. –

"Exfoliative Cytology in the Study of Ascites Tumors" – Irena Koprowska, Kings County Hospital, Brooklyn, N. Y.

Discussion: G. Klein, Institute for Cell Research & Genetics, Karolinska Institutet, Stockholm, Sweden.

"Electron Microscope Studies on Ascites Tumors" – Cecily C. Selby, John J. Biesele, and Clifford E. Grey, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

Discussion: Albert J. Dalton, National Cancer Institute, Bethesda, Md.

"Chromosomes in Cancer Tissue" – Albert Levan, University of Lund, Lund, Sweden.

Discussion: George Yerganian, Children's Cancer Research Foundation, Boston, Mass.

"Cytologic Variability in Human Carcinomatosis" – P. C. Koller, The Chester Beatty Research Institute, The Royal Cancer Hospital, London, England.

Discussion: Cecelia Leuchtenberger, Western Reserve University, Cleveland, Ohio.

"Chromosome Patterns in Rat Ascites Tumors" – Sajiro Makino, Hokkaido University, Sapporo, Japan. (To be read by title.)

"Changes in Nuclear DNA in Normal and Ascites Tumor Cells" – Peter M. B. Walker, King's College, London, England.

Discussion: Montgomery J. Moses, Brookhaven National Laboratory, Upton, L.I., N.Y.

CYTOLOGIC MERITS OF ASCITES TUMORS *(Continued)*

Session Chairman: Hans Lettré
Universität Heidelberg, Heidelberg, Germany

8:00 P.M. –

"Film Demonstration of *In Vitro* Growth of the Yoshida Ascites Sarcoma" – Annelies Schleich, Johns Hopkins Hospital, Baltimore, Md.

"Contributions of the Ascites Hepatoma to the Concept of Grade of Malignancy" – Tomizo Yoshida, University of Tokyo Medical School, Tokyo, Japan.

Discussion: M. J. Kopac, New York University, New York, N. Y.

"The Value of Ascites Tumors in Problems of Tumor Immunity" – Peter A. Gorer, Guy's Hospital Medical School, London, England.

Discussion: Eugene Day, Roswell Park Memorial Institute, Buffalo, N. Y.

FRIDAY, MAY 20, 1955

ASCITES TUMORS AS ASSAY TOOLS

Session Chairman: Jacob Furth
Children's Cancer Research Foundation, Inc., Boston, Mass.

9:00 A.M. –

"Ascites Tumors as Culture Media in Quantitative Growth Studies of Viral Agents" – Hilary Koprowski, Lederle Laboratories Division, American Cyanamid Co., Pearl River, N. Y.

Discussion: Robert Love, Lederle Laboratories, Pearl River, N. Y., and Alice E. Moore, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Autoradiographic Studies with C14-Adenine on Ehrlich Mouse Ascites Tumor Cells" – Alma Howard, Hammersmith Hospital, London, England.

"Possibilities of Autoradiographic Studies with Ascites Tumors" – S. R. Pelc, Hammersmith Hospital, London, England.

Discussion: David Pressman, Roswell Park Memorial Institute, Buffalo, N. Y.

"Radiation Effects on Ascites Tumor Chromosomes" – Alan D. Conger, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Discussion: Arnold H. Sparrow, Brookhaven National Laboratories, Upton, L.I., N.Y.

"Labelled Ascites Cells (P32) in the Study of Metastasis" – Julian and Klara Ambrus, Philadelphia College of Pharmacy, Philadelphia, Pa.

Discussion: Irving Zeidman, University of Pennsylvania Medical School, Philadelphia, Pa.

"Merits of Ascites Tumors for Chemotherapeutic Screening" – Kanematsu Sugiura, Sloan-Kettering Institute, New York, N. Y., and Hugh J. Creech, Institute for Cancer Research, Philadelphia, Pa.

Discussion: Alfred Gellhorn, Columbia University, Institute of Cancer Research, New York, N. Y.

ADVANTAGES OF FREE CELL SUSPENSIONS FOR METABOLIC STUDIES

Session Chairman: Sidney Weinhouse
Institute for Cancer Research, Philadelphia, Pa.

2:00 P.M. –

"Comparative Metabolic Study of MC1M Ascites and a Suspension of Whole Cells Obtained from MC1M Solid Tumor" – John Kaltenbach and M. H. Kaltenbach, Veteran's Administration Research Hospital, Chicago, Ill.

Discussion: Gerald A. LePage, University of Wisconsin, Madison, Wis.

"Concentrative Uptake of Amino Acids by Free-Cell Neoplasms" – Halvor N. Christensen, Tufts College Medical School, Boston, Mass.

Discussion: George B. Brown, Sloan-Kettering Institute, New York, N. Y.

"Amino-Peptidase Content as Correlated with Chromosome Constitution in Sublines of the Ehrlich Ascites Tumor" – Elizabeth Patterson, Institute for Cancer Research, Philadelphia, Pa.

Discussion: Mary E. Maver, National Cancer Institute, Bethesda, Md.

"Studies of Nucleic Acid Synthesis in Ascites Tumor Cells" – Gerald A. LePage, University of Wisconsin, Madison, Wis.

Discussion: Charles Wenner, Institute for Cancer Research, Philadelphia, Pa.

"Respiratory Pigments in Malignant Cells" – Britton Chance, Johnson Foundation for Medical Physics, Philadelphia, Pa.

Discussion: Efraim F. Racker, The Public Health Research Institute of the City of New York, Inc., New York, N. Y.

Session Chairman: G. Klein
Institute for Cell Research & Genetics
Karolinska Institutet, Stockholm, Sweden

8:00 P.M. –

"Resistance to Colchicine, Trypaflavine and Radiation in Selected Sublines of the Ehrlich Ascites Tumor" – Hans Lettré, Universität Heidelberg, Heidelberg, Germany.

Concluding Remarks – Alexander Haddow, Chester Beatty Research Institute, Royal Cancer Hospital, London, England.

SECTION OF BIOLOGY

NUTRITION IN INFECTIONS

Tuesday, May 24 and
Wednesday, May 25, 1955

Conference Chairman: W. A. Wright
Medical Director, Pfizer Laboratories,
Division Chas. Pfizer & Co., Inc.,
Brooklyn, N. Y.

TUESDAY, MAY 24, 1955

Session Chairman: Norman H. Jolliffe
Director, Bureau of Nutrition, Department of Health,
City of New York, N. Y.

9:00 A.M. –

Introductory Remarks – Hilary Koprowski, Chairman, Section of Biology, The New York Academy of Sciences, New York, N. Y.; Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

"Critical Evaluation of the Role of Nutrition in the Prophylaxis and Treatment of Disease" – Seymour Lionel Halpern, New York Medical College, Flower Fifth Avenue Hospital, New York, N. Y.

"Implications of Observations During Experimental Deficiencies in Man" – Max K. Horwitt, Elgin State Hospital, Elgin, Ill.

"Nutrition and Intestinal Parasitism" – William W. Frye, Louisiana State University School of Medicine, New Orleans, La.

"Comparative Efficacy Against Experimental Infection in Mice–Antibiotics Alone and with Vitamin Mixture" – Arthur English, Pfizer Therapeutic Institute, Maywood, N. J.

"Effects of High Levels of Vitamins on the Resistance of Chicks to

Fowl Typhoid" – C. H. Hill, North Carolina College of Agriculture and Engineering, Raleigh, N. C.

General Discussion

2:00 P.M. –

"B-Vitamins and Antibiotics in the Treatment of Swine Enteritis" – R. W. Luecke, Michigan State College, East Lansing, Mich.

"Relationship of Vitamins to Antibody Formation" – A. E. Axelrod, University of Pittsburgh, Pittsburgh, Pa.

"Observations on Infection and Certain Vitamins" – Benjamin M. Kagan, Michael Reese Hospital, Chicago, Ill.

"Fluid Balance during Infection, with Reference to Mineral and Protein Metabolism Enzyme Systems" – Joachim Kühnau, Physiological Chemical Institute, University of Hamburg, Hamburg, Germany.

General Discussion

WEDNESDAY, MAY 25, 1955

Session Chairman: Henry Welch
Director, Division of Antibiotics, Food & Drug Administration
Department of Health, Education & Welfare, Washington, D. C.

9:00 A.M. –

"Fortified Broad Spectrum Antibiotics as an Adjunct in Surgical Treatment of the Young, and the Aged and Debilitated" – Aaron Prigot, Harlem Hospital, New York, N. Y.

"Nutritional and Metabolic Aspects of Infection" – Laurance Kinsell, Highland Alameda County Hospital, Oakland, Calif.

"Antibiotics and Nutrition in Infections" – Max B. Milberg, Maimonides Hospital, Brooklyn, N. Y., and Max Michael, Jr., State University College of Medicine, New York, N. Y.

"Nutritional Deficiency as It Predisposes to Infection, and the Role of Vitamin Deficiencies" – Ruben Lopez-Toca, University of Havana Medical School, Havana, Cuba.

General Discussion

2:00 P.M. –

"Nutritional Problems of Surgical Patients" – Jonathan Evans Rhoads, University of Pennsylvania School of Medicine, Philadelphia, Pa.

"Deficiency Syndromes of the Tropics – Causal Relations, Prevention and Treatment" – Elmer H. Loughlin and William G. Mullin, New York Medical College and Flower Fifth Avenue Hospital, New York, N. Y.

"Altered Prognosis in the Diabetic with Infection" – Herbert Pollack, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"Recapitulation and Prospects" – Howard A. Schneider, Rockefeller Institute for Medical Research, New York, N. Y.

Concluding Remarks – Henry Welch, Division of Antibiotics, Food & Drug Administration, Department of Health, Education and Welfare, Washington, D. C.

SECTION OF BIOLOGY

AND

THE DAMON RUNYON MEMORIAL FUND FOR CANCER RESEARCH, INC.

CANCER CYTOLOGY AND CYTOCHEMISTRY

Thursday, May 26, Friday, May 27 and Saturday, May 28, 1955

Conference Chairman: M. J. Kopac
Graduate School of Arts & Science, New York University, New York, N.Y.

THURSDAY, MAY 26, 1955

GENERAL PROBLEMS IN CANCER CYTOLOGY

Session Chairman: Joe V. Meigs
Vincent Memorial Hospital, Boston, Mass.

9:00 A.M. –

Greetings from the Academy – Hilary Koprowski, Chairman, Section of Biology, New York Academy of Sciences, New York City; Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

The Conference and Its Aims – M. J. Kopac, Conference Chairman, Graduate School of Arts and Science, New York University, New York, N.Y.

"The Inter-Society Cytology Council" – Joe V. Meigs, Session Chairman, Vincent Memorial Hospital, Boston, Mass.

"Malignant Properties of Cancer Cells" – E. V. Cowdry, Division of

Cancer Research, Washington University, School of Medicine, St. Louis, Mo.

"Early Uterine Cancer Detection by Cytologic Screening" – Cyrus C. Erickson, Institute of Pathology, University of Tennessee, Memphis, Tenn.

"Teamwork between Pathologists and Cytologists" – Paul Klemperer and Louis Lapid, The Mount Sinai Hospital, New York, N. Y.

"Accomplishments and Shortcomings of Cancer Cytology" – Emerson Day, Strang Cancer Prevention Clinic, Memorial Center, New York, N. Y.

MORPHOLOGIC IMPRINTS OF MALIGNANCY ON CELLS

Session Chairman: William R. Duryee
Carnegie Institution at Washington, Washington, D. C.

2:00 P.M. –

"The Characteristics of Mitosis in Tumor Cells" – Ross C. MacCardle, National Cancer Institute, Bethesda, Md.

"Chromosomal Anomalies in Human Neoplastic Cells" – T. C. Hsu and Paul S. Moorhead, University of Texas – Medical Branch, Galveston, Tex.

"Nucleolar Variability in Human Neoplastic Cells" – Margaret E. Long, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"A Cytomorphologic Orientation of Intra-Epithelial Carcinoma and Atypical Hyperplasia of the Uterine Cervix" – Alvan G. Foraker, Baptist Memorial Hospital, Jacksonville, Fla.

"Electron Microscopy of Cytoplasmic Components in Normal and Malignant Cells" – Albert J. Dalton and Marie D. Felix, National Cancer Institute, Bethesda, Md.

FRIDAY, MAY 27, 1955

SPECIALIZED DEVELOPMENTS IN CYTOCHEMISTRY

Session Chairman: M. J. Kopac
Graduate School of Arts and Science, New York University, New York, N.Y.

9:00 A.M.

"Applications of Soft X-Ray Absorption Methods to Normal and Neoplastic Cells" – Patrick J. Fitzgerald, State University Medical Center at New York, Brooklyn, N. Y.

"Quantitative Cytology and Cytopathology: Nucleic Acids and Proteins in the Mitotic Cycle" – Robert C. Mellors, Sloan-Kettering Institute for Cancer Research, Memorial Center, New York, N. Y.

"Evaluation of the Ultraviolet Color Translating Microscope" – Ruth M. Graham and Ruth Crozier, Vincent Memorial Hospital, Boston, Mass.

"Automatic Screening of Cytologic Smears for Cancer: The Instrumentation" – Walter E. Tolles and Roland C. Bostrom, Airborne Instruments Laboratory, Inc., Mineola, N. Y.

"Topological Cytochemistry" – M. J. Kopac, Graduate School of Arts and Science, New York University, New York, N. Y.

THE CYTOLOGY OF EARLY CANCER

Session Chairman: H. E. Nieburgs
Beth-El Hospital, Brooklyn, N. Y.

2:00 P.M. –

"Dysplasia of the Uterine Cervix" – James W. Reagan and Marcel J. Hamonic, Institute of Pathology, Western Reserve University, Cleveland, Ohio.

"Unusual Patterns of Squamous Epithelium of the Uterine Cervix: Cytologic and Pathologic Study" – Leopold G. Koss and Grace R. Durfee, Strang Laboratory of Cytology and Pathology Laboratories, Memorial Center, New York, N. Y.

"The Pre-Cancer Cell: A New Problem in Cancer Research" – J. Ernest Ayre, Cancer Institute at Miami, Miami, Florida.

"Cellular Changes Induced by Inflammation" – Elliott D. Blumenthal and E. L. Hecht, University Hospital, New York University – Bellevue Medical Center, New York, N. Y.

"Pre-Cancer Cells in Amphibian Adenocarcinoma" – William R. Duryee, Carnegie Institution, Washington, D. C.

"Some Early Changes in Epidermal Carcinogenesis Examined with New Techniques" – John J. Biesele, A. R. T. Denues, Clifford E. Grey, and Frances C. Mottram, Sloan-Kettering Institute for Cancer Research, Memorial Center, New York, N. Y.

8:30 P.M. –

Round-Table Panel Discussion –

A NEW LOOK AT THE PRE-CANCER CELL

Moderator: James W. Reagan
Institute of Pathology, Western Reserve University, Cleveland, Ohio.

Panel: Conference Speakers and Session Chairmen

SATURDAY, MAY 28, 1955

PERSPECTIVES IN CANCER CYTOLOGY: .

Session Chairman: Emerson Day
Strang Cancer Prevention Clinic, Memorial Center, New York, N. Y.

9:00 A.M. –

"Identification of Cells in Exudates and Effusates" – N. Chandler Foot, Cornell University Medical College, New York, N. Y.

"A Histocytologic Study of Effusions Associated with Malignant Disease" – Sarah A. Luse and James W. Reagan, Washington University, School of Medicine, St. Louis, Mo., and Institute of Pathology, Western Reserve University, Cleveland, Ohio.

"Aspiration Biopsy and Its Application" – John T. Godwin, Saint Joseph's Infirmary, Atlanta, Ga.

"Cytology of Pulmonary Carcinoma" – Peter A. Herbut, Jefferson Medical College and Hospital, Philadelphia, Pa.

"Newer Advances in the Exfoliative Cytology of the Gastro-Intestinal Tract" – Cyrus E. Rubin, Department of Medicine, University of Washington, Seattle, Wash.

"The Cytology of Endometrial Cancer" – E. L. Hecht, University Hospital, New York University – Bellevue Medical Center, New York, N. Y.

PERSPECTIVES IN CANCER CYTOLOGY: II

Session Chairman: Raymond F. Kaiser
National Cancer Institute, Bethesda, Md.

2:00 P.M. –

"Cytologic Evaluation of Breast Secretions" – George N. Papanicolaou, Genevieve M. Bader, Doris G. Holmquist, and Emil A. Falk, Cornell University Medical College; Strang Cancer Prevention Clinic, Memorial Center; and New York Hospital, New York, N. Y.

"Exfoliative Cytology of the Mammary Gland during Pregnancy and Lactation" – Doris G. Holmquist and George N. Papanicolaou, Cornell University Medical College, New York, N. Y.

"Cytologic-Tissue Culture Studies on Cervical Epithelium" – C. G. Grand, Cancer Institute at Miami, Miami, Fla.

"Exfoliative Cytology as Applied to the Quantitative Evaluation of Oncolysis Induced by Viruses" – Irena Koprowska, State University Medical Center at New York, Brooklyn, N. Y.

"Studies on Nucleoprotein Patterns in Radiosensitivity Testing" – Saul B. Gusberg, Margaret E. Long, and Harold M. M. Tovell, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"The Sensitization Response in the Vaginal Smear" – John B. Graham and Ruth M. Graham, Vincent Memorial Hospital, Boston, Mass.

Concluding Remarks.

NEW MEMBERS

Elected May 16, 1955

SUSTAINING MEMBERSHIP

Rugh, Charles V., M.D., Medicine. Private Practice, Klamath Falls, Ore.
Sutton, Myrwood B., M.D., Medicine. Private Practice, New Philadelphia, Ohio.

ACTIVE MEMBERSHIP

Bernegger, Rolf, Ph.D., Organic Chemistry. Plant Manager, Alrose Chemical Corp., Providence, R.I.
Biringer, Steven I., M.D., Ophthalmology. Private Practice, Mexico City D.F., Mexico.
Bogert, Virgil V., Ph.D., Organic Chemistry. Research Associate, Chas. Pfizer & Co., Inc., Brooklyn, N.Y.
Breinig, Carolyn R., B.A., Bacteriology. Graduate Student, Lehigh University, Bethlehem, Pa.
Cabal, Pedro P., M.D., Surgery. Surgeon, Asociacion Cubana de Beneficencia Clinic, Havana, Cuba.
Corum, Cyril J., Ph.D., Antibiotics. Department Head, Fermentation Development and Assay Laboratories, Eli Lilly & Co., Indianapolis, Ind.
Curtis, Robin L., Ph.D., Physiological Psychology. Research Associate, Department, Biology, Brown University, Providence, R.I.
Daniels, Robert Paul, M.S., Mycology. Research Assistant, Purdue University, West Lafayette, Ind.
Dowling, Richard A., B.S., Endocrinology. Medical Technician, U.S. Army Dispensary, Fort Tilden, N.Y.
Gratton, Laurent, M.D., Serology. Private Practice, Granby, P.Q., Canada.
Haag, Harvey B., M.D., Pharmacology. Professor, Pharmacology, Medical College of Virginia, Richmond, Va.
Hackler, R.H., M.D., Radiology. Taylor Hospital Inc., Washington, North Carolina.
Heydt, Georgine E., Nursing, Psychiatry. Private Practice, Nursing, Cliffside Park, N.J.
Higgins, Thomas F., M.D., Medicine. Co-ordinator, Intern Teaching, Union Hospital, Fall River, Mass.
Hill, Franklyn C., Jr., M.D., Medical Neurology. Assistant Resident, Medicine, Highland-Alameda County Hospital, Oakland, Calif.
Hill, Joseph MacGlashan, M.D., Hematology. Director, Wadley Research Institute & Blood Bank; Dean, Graduate Research Institute, Baylor University, Dallas, Tex.
Hood, John J., M.S., Plant Pathology. Technical Advisor, Geigy Agricultural Chemicals, New York, N.Y.
Hopkinson, Merwyn Alexander, M.D., Biology. Private Practice, Lion's Head, Ont., Canada.
Hortenstine, John C., M.D., Internal Medicine. Private Practice, Winchester, Va.
Huber, Carl Parker, M.D., Obstetrics. Professor, Chairman, Department, Obstetrics, Indiana University School of Medicine, Indianapolis, Ind.
Hudgins, A. P., M.D., Medicine. Private Practice, Charleston, West Va.
Hudson, Willard P., M.D., Medicine. Private Practice, Forest Hill, Md.
Huppert, Curtis Roy, Ph.D., Medical Rehabilitation. Director, Physical Medicine and Rehabilitation, Saw Mill River Rehabilitation Center, Yonkers, N.Y.
Jaudon, Joseph C., M.D., Pediatrics. Private Practice, St. Louis, Mo.
Johnson, Amil John, M.D., Medicine. Private Practice, Palo Alto, Calif.
Johnson, Leland P., Ph.D., Biology. Professor, Biology, Drake University, Des Moines, Iowa.
Kalfayan, Bernard, M.D., Immuno-Cytology. Assistant Professor, Pathology, Columbia University, New York, N.Y.
Kelly, William E., M.D., Psychiatry. Private Practice, Psychiatry, Philadelphia, Pa.

Kirk, Billy E., B.S., Bacteriology. Graduate Assistant, Ohio State University, Columbus, Ohio.

Kitchin, Donald W., B.S., Physics. Research Laboratory, Simplex Wire and Cable Company, Cambridge, Mass.

Kleh, Jack, M.D., Cardiovascular Disease. Private Practice, Washington, D.C.

Klein, Robert, M.D., Pediatric Endocrinology. Associate Professor, Pediatrics, Children's Hospital of Pittsburgh, Pittsburgh, Pa.

Klenner, Frederick Robert, M.D., Biochemistry. Private Practice, Reidsville, N.C.

Klingman, Walter O., M.D., Neurology. Professor, Neurology, Psychiatry, University of Virginia, Charlottesville, Va.

Kronemeyer, Robert F., D.Ed., Psychotherapy. Director, Huntington Psychological Center, Private Practice, New York, N.Y.

Kruesi, Oscar Rogers, M.D., Biology. Chief Resident, Medicine, St Luke's Hospital, New York, N.Y.

Kuss, Frederick Richard, M.S., Plant Pathology. Technical Representative, California Spray Chemical Corporation, Laconia, N.H.

Langroa, Bronislawa, Ph.D., Psychology. Private Practice, New York, N.Y.

Lederman, Bernard, M.D., Medicine. Assistant, Professor, Obstetrics, Boston University School of Medicine, Boston, Mass.

Legator, Marvin, Ph.D., Microbiology. Senior Microbiologist, Shell Development Company, Modesto, Calif.

Lipton, Morris A., M.D., Medicine. Chief, Investigative Medicine, Veterans Administrative Hospital, Chicago, Ill.

Mandelbaum, Theodore, M.D., Medicine. Associate Attending Meadowbrook Hospital, Rockville Center, N.Y.

Mansmann, James A., M.D., Allergy. Private Practice, Pittsburgh, Pa.

Marquez, Cecil, M.D. Internal Medicine. Associate Physician, Harlem Hospital, New York, N.Y.

Marshak, Robert R., D.V.M., Metabolic Diseases, Animals. Private Practice, Veterinarian, Springfield, Vt.

May, Ernest M., Ph.D., Synthetic Organic Chemistry. President, Otto B. May, Inc., Newark, N.J.

Nappi, Raffaele, M.D., Obstetrics, Gynecology. Medical Officer, American Consultate General, Naples, Italy.

Nardelli, Lino, Virology. Assistant Chief, Instituto Zooprofilattico, Brescia, Italy.

Nathan, Paul, Ph.D., Neuropharmacology. Biochemist, State Research Hospital, Galesburg, Ill.

Naumberg, Margaret, B.A., Psychology. Department Clinical Psychiatry, New York Psychiatric Institute, New York, N.Y.

Olsen, Perry A., M.D., Medicine. Private Practice, Woodland, Calif.

Oshlag, Abraham M., M.D., Biology. Private Practice, Griffin, Ga.

Partanen, Carl R., Ph.D., Cytology, Biology. Research Fellow, Department, Zoology, Columbia University, New York, N.Y.

Pensler, Leslie, M.D., Pediatrics. Private Practice, Detroit, Mich.

Pisanty, Jose, M.D., Physiology. Professor, Head, Department, Physiology, Medical School of Guadalajara, Guadalajara, Jal., Mexico,

Podolsky, Edward, M.D., Psychiatry. Assistant Visiting Psychiatrist, Kings County Hospital, Brooklyn, N.Y.

Polson, Robert Alexander, M.D., Medicine, Nutrition. Lecturer, Medicine, University of Manitoba, Winnipeg, Man., Canada.

Preud'homme, Jean, E.N.S.C.P., Physics, Chemistry. Ingénieur Chimiste à la Société des Usines Chimiques Rhone-Poulenc, Paris, France.

Rajou, Rangaswamy A., B.Sc., Medicine. Fellow, Pathology, University of Pennsylvania, Philadelphia, Pa.

Reardon, James Jeremiah, M.D., Internal Medicine. Attending Physician, Electrocardiographer, Champlain Valley Hospital, Plattsburg, N.Y.

Rees, William J., M.D., Medicine. Consultant, U.S. Government, Arlington, Va.

Rhodes, George J., M.D., Internal Medicine. Instructor, Medicine, University of Pittsburgh, Pittsburgh, Pa.

Roehm, Dan Christian, M.D., Medicine. Assistant Clinical Instructor, Vanderbilt University School of Medicine, Nashville, Tenn.

Roth, Nathan, M.D., Psychiatry. Assistant Clinical Professor, Psychiatry, New York Medical College, New York, N.Y.

Rottenstein, Hans S., M.D., Anesthesiology. Assistant Professor, University of Pennsylvania, Philadelphia, Pa.

Ryan, Sylvester J., M.D., Biology, Medicine. Chief, Medicine, U.S.A.F. Hospital, Glendale, Ariz.

Sainz, Anthony, M.D., Psychiatry. Psychiatrist, Rockland State Hospital, Orangeburg, N.Y.

Saline, Myron, M.D., Medicine. Private Practice, Laurelton, N.Y.

Scala, Robert A., B.A., Anti-metabolite Studies. Graduate Fellow, Department, Physiology, University of Rochester, Rochester, N.Y.

Shelokov, Alexis, M.D., Infectious Diseases. Surgeon, Laboratory of Infectious Diseases, National Institutes of Health, Bethesda, Md.

Sidbury, James B., Jr., M.D., Pediatrics. Instructor, Pediatrics, Johns Hopkins Hospital, Baltimore, Md.

Siegman, C. Joseph, M.D., Tuberculosis. Assistant Physician, Chest Clinic, Maimonides Hospital, New York, N.Y.

Slater, Nathan M., M.A., Counseling Psychology. Supervisor, Industrial Rehabilitation Unit, New York, N.Y.

Smith, Ernest Lester, D.Sc., Biochemistry. Senior Biochemist, Glaxco Laboratories Ltd., Greenford, Middlesex, England.

Stoll, William R., B.S., Pharmacology. Graduate Student, Department, Pharmacology, University of Rochester, Rochester, N.Y.

Thuringer, J. M., M.D., Histopathology. Pathologist, Chief, Laboratory Service, Veterans Administration Hospital, Fayetteville, Ark.

Thurman, George Edward, M.D., Medicine, Surgery. Surgeon, Harlingen, Texas.

Tovee, E. B., M.D., Surgery. Senior Surgeon, Toronto General Hospital, Toronto, Ont., Canada.

Wallach, Donald Francis Hoelzl, M.D., Medicine. Assistant, Research, Peter Bent Brigham Hospital, Boston, Mass.

Wang, Ging H., M.D., Otology. Fellow, Laryngology and Otology, Johns Hopkins University, Baltimore, Md.

Weiss, Jess B., M.D., Anesthesiology. Fellow, Anesthesiology, Massachusetts Memorial Hospitals, Boston, Mass.

Wells, Benjamin B., M.D., Medicine. Professor, Medicine, The Creighton University, Omaha, Neb.

Wied, George L., M.D., Cytology. Assistant Professor, Obstetrics, University of Chicago, Chicago, Ill.

STUDENT MEMBERSHIP

Brooks, Alfred J., M.S., Psychology. Graduate Student, Columbia University, New York, N.Y.

Goldman, Lillian, M.A., Psychology. Student, National Psychological Association for Psychoanalysis, New York, N.Y.

Elected May 27, 1955

LIFE MEMBERSHIP

Sakel, Manfred, D.Sc., M.D., Medicine, Psychology. Research Scientist, New York, N.Y.

SUSTAINING MEMBERSHIP

Kasper, E. Carroll, M.D., Psychology, Biology. Private Practice, Grafton, Ohio.

Knoll, Isaac, M.D., Medicine, Psychology, Anthropology, Chemistry. Physician, Surgeon, Sitka Community Hospital, Sitka, Alaska.

Kuss, Ernst, Ph.D., Chemistry, Physics. Director, Vorsitzender des Vorstandes, Duisburg, Germany.

Lurie, Robert I., M.D., Biology. Private Practice, Saginaw, Mich.

Mitchell, J. West, M.D., Diabetes. Associate Clinical Professor, Medicine, University of Pittsburgh, Pittsburgh, Pa.

Oster, Edwin A., M.D., Biology, Psychology. Private Practice, Los Gatos, Calif.

Purinton, William A., M.D., Surgery. Assistant Attending Surgeon, East Maine General Hospital, Bangor, Me.

ACTIVE MEMBERSHIP

Adel, Harold N., M.D., Internal Medicine. Intern, Long Island College Hospital, Brooklyn, N.Y.

Alexopoulos, Constantine J., Ph.D., Mycology. Professor, Botany, Michigan State University, East Lansing, Mich.

Ashley, Catherine C., B.S., Biochemistry. Biochemist, Technical and Administrative Supervisor, General Medical Research Laboratories, Veterans Administration Hospital, Coral Gables, Fla.

Berg, Benjamin N., M.D., Experimental Pathology. Associate, Pathology, Columbia College of Physicians and Surgeons, New York, N.Y.

Bunting, Mary I., Ph.D., Microbial Genetics. Dean, Douglass College, Rutgers University, New Brunswick, N.J.

Colombo, Carmelo, B.S., Pharmacology. Pharmacology Research Assistant, United States Vitamin Company, Yonkers, N.Y.

Coyle, William R., III, B.A., Physiology, Medicine. New York University-Bellevue Medical Center, New York, N.Y.

Demaar, Edmund William John, M.D., Neuropharmacology. Assistant Professor, Pharmacology, University of Illinois, Chicago, Ill.

Demelfy, F. A., M.D., Physiological Chemistry. Layman, Kansas City, Mo.

Gottschalk, Carl, M.D., Biology. New York, N.Y.

Grifoni, Vincenzo, M.D., Hematology. Assistant Professor, Department, Medical Pathology, Milan University, Milan, Italy.

Haymond, H. R., Ph.D., Biophysics. Assistant Professor, Radiology, University of Southern California, Los Angeles, Calif.

Hefferline, Ralph Franklin, Ph.D., Psychology. Assistant Professor, Psychology, Columbia University, New York, N.Y.

Hendrickson, Anna R., M.D., Medicine. Private Practice, Canton, Ohio.

Herter, Walter Beh, M.D., Pediatrics. Private Practice, Honolulu, Hawaii.

Hightower, Felda, M.D., General Surgery. Associate Professor, Surgery, Bowman Gray School of Medicine, Winston-Salem, N.C.

Hill, Elizabeth H., M.D., Biology. Director, Out Patients Department, D.C. General Hospital, Washington, D.C.

Hirsch, Sol, M.D., Migraine Headache. Internist, New York, N.Y.

Hitrec, William Stephen, M.D., Radiology, Cancer Research. Owner, Floyd County Clinic and Hospital, Floyd, Va.

Huang, Beulah, M.D., Pathology. Resident Pathologist, Bronx Municipal Hospital Center, New York, N.Y.

Huffman, John W., M.D., Gynecology. Private Practice, Chicago, Ill.

Humbrecht, Mary, M.D., Internal Medicine. Resident Physician, Baptist Hospital, New Orleans, La.

Hunt, Charles L., M.D., Geology, Biology, Anthropology, Physics, Chemistry. Private Practice, West Vancouver, B.C., Canada.

Hutaff, Lucile W., M.D., Hematology. Acting Director, Department, Preventive Medicine, Bowman Gray School of Medicine, Winston-Salem, N.C.

Hyman, Julian B., M.D., Internal Medicine. Private Practice, New York, N.Y.

Kahn, Isador W., M.D., Gynecology, Obstetrics. Attending Obstetrics, Gynecology, University Hospital, New York, N.Y.

Kamen, George F., M.D., Biology, Clinical Investigation. Private Practice, New York, N.Y.

Kamens, Edward A., M.D., Surgery, Surgical Research. Assistant Resident Surgeon, Maimonides Hospital, Brooklyn, N.Y.

Karelitz-Karry, Marie, M.D., Pigmentation of Skin. Assistant in Dermatology, Vanderbilt Clinic, New York, N.Y.

Karfiol, Sigmund, M.D., Biology. Private Practice, Brooklyn, N.Y.

Karpel, Bernard, M.D., Medicine. Private Practice, Mooresville, Ind.
Kasinoff, Bernard H., M.D., Psychiatry. Private Practice, New York, N.Y.
Katsas, George Gregory, M.D., Medicine, Legal Medicine. Department, Legal Medicine, Harvard Medical School, Boston, Mass.
Kinsella, Dalton Louis, Jr., M.D., Medical Research, Medicine. Fellow in Pathology, Jackson Memorial Hospital, Miami, Fla.
Kirshen, Martin Marcell, M.D., Internal Medicine. Associate Professor, Clinical Medicine, Chicago, Ill.
Klein, Howard Albert, M.D., Internal Medicine. Private Practice, Detroit, Mich.
Kling, David, M.D., Rheumatic Diseases. Medical Director, Boyar-Kling Arthritis Clinic, Los Angeles, Calif.
Knight, Granville Frank, M.D., Allergy, Nutrition. Private Practice, Santa Barbara, Calif.
Kroger, William S., M.D., Psychosomatic Medicine. Associate Professor, Gynecology, Chicago Medical School, Chicago, Ill.
Lehine, David E., M.D., Biology, Psychology, Anthropology. Consulting Physician, United Nations Health Service, New York, N.Y.
Lin, Ku Yin, M.D., Pathology. Fellow in Pathology, Cleveland City Hospital, Cleveland, Ohio.
Lind, Arthur, M.D., Internal Medicine. Captain United States Army, Murphy Army Hospital, Waltham, Mass.
Lionello, Joseph, M.D., Biology. Attending Surgeon, Holy Family Hospital, Brooklyn, N.Y.
Lord, W. Burton, Medicine. Whittier Laboratories, Chicago, Ill.
Lorenz, Thomas H., M.D., Medicine. Assistant Professor, Medicine, University of Wisconsin Hospitals, Madison, Wis.
Loyke, Hubert F., M.D., Medicine. Captain USAF, Chief of Medical Service, 4450th USAF Hospital, Langley Air Force Base, Va.
Luikart, William M., M.D., Internal Medicine. Private Practice, Baton Rouge, La.
McAllister, Robert M., M.D., Virology, Tissue Culture. Associate in Pediatrics, University of Pennsylvania, Philadelphia, Pa.
McArdle, John Stephen, M.D., Medicine. Consultant in Medicine, St. Joseph's Hospital, Minot, N.D.
McCann, William S., M.D., Medicine. Physician in chief, Strong Memorial Hospital, Rochester, N.Y.
MacDonald, Maxwell E., M.D., Neurology. Consultant Neurologist, Boston, Mass.
MacKenzie, Walter C., M.D., Surgery. Professor, Surgery, University of Alberta, Edmonton, Alta., Canada.
McLendon, Preston A., M.D., Nutrition. Professor, Pediatrics, George Washington University, Washington, D.C.
McLennan, John E., M.D., Biology. Private Practice, Palos Verdes Estates, Calif.
Mac Neill, Arthur E., M.D., Medical Research. Director, Laboratories, Chronic Disease Research Institute, University of Buffalo School of Medicine, Buffalo, N.Y.
McNicol, H. L., M.D., Medicine. Private Practice, Flin Flon, Man., Canada.
Maeth, Harry, D.D.S., Dental Materials. Private Practice, Dentistry, Mosinee, Wis.
Marshall, James S., M.D., Biology. Private Practice, Farmington, Conn.
Martin, Marion, M.A., Rehabilitation. Supervisor, School Service Unit, Division of Vocational Rehabilitation, New York State Educational Department, New York, N.Y.
Martin, W. Coda, M.D., Biology. Private Practice, New York, N.Y.
Merrill, George G., M.D., Neurology, Psychiatry. Assistant Professor, Neurology, University of Maryland, Baltimore, Md.
Michaud, Jean Berchmans, M.D., Medicine. Private Practice, Drummondville, P.Q., Canada.
Millet, John Bradford, M.D., Medicine. Private Practice, Utica, N.Y.
Minor, Howard Holland, M.D., Surgery. Private Practice, Steubenville, Ohio.
Molholm, Hans B., M.D., Biology. Director, Biochemical Research Laboratory, Columbus State Hospital, Columbus, Ohio.
Montilla, Eduardo, M.D., Internal Medicine. Private Practice, Santurce, Puerto Rico.

Morales, Alfredo Torrico, M.D., Medical Mycology. Fellow, Institute Oswaldo Cruz, Rio de Janeiro, Brazil.

Moscovici, Carlo, Ph.D., Virology. Assistant, Research, Instituto Superiore di Sainta, Rome, Italy.

Nashold, Blaine S., Jr., M.D., Neurological Sciences. Resident, Neurological Surgery, Bowman Gray Medical School, Winston-Salem, N.C.

Nechtow, Mitchell J., M.D., Obstetrics, Gynecology. Private Practice, Chicago, Ill.

Nedelkoff, Bogdan, M.D., Biology. Resident Physician, New Jersey Sanatorium for Chest Diseases, Glen Gardner, N.J.

Netto, Lauro Ayres da Gama Bastos, M.D., Parasitology. Fellow, Institute Oswaldo Cruz, Rio de Janeiro, Brazil.

Neustader, A., M.D., Biology. Private Practice, Far Rockaway, N.Y.

Ney, Charles, M.D., Urology. Attending Urologist, Morrisania City Hospital, New York, N.Y.

Noble, Robert Laing, D.Sc., Endocrinology. Professor, Associate Director, Collip Medical Research Laboratory, University of Western Ontario, London, Ont., Canada.

Noce, Robert H., M.D., Chemotherapy of the Mentally Ill. Director, Clinical Services, Modesto State Hospital, Modesto, Calif.

Nordlicht, Stephen, M.D., Psychiatry. Private Practice, New York, N.Y.

Nutting, Leighton A., Ph.D., Microbiology. Scientist, National Dairy Research Laboratories Inc., Oakdale, N.Y.

Oclander, Gregorio, M.D., Pediatric Nutrition. E. R. Squibb & Sons, International Division, New York, N.Y.

O'Neal, H.E., M.D., Biology. Private Practice, Tipton, Iowa.

Oster, Harold L., M.D., Internal Medicine. Resident II, Wayne County General Hospital, Eloise, Mich.

Osterman, Arthur Lee, M.D., Neurology, Psychiatry. Psychiatrist, Wheeling, W. Va.

Overman, John R., M.D., Virus Research. Assistant, Rockefeller Institute for Medical Research, New York, N.Y.

Patterson, John L., Jr., M.D., Internal Medicine. Associate Professor, Medicine, Medical College of Virginia, Richmond, Va.

Perez, Willy M., M.D., Peripheral Vascular Diseases. Senior Assistant, Mt. Sinai Hospital, New York, N.Y.

Perry, Vernon Paul, LL.B., Biology. Senior Instructor, Tissue Bank School, Naval Medical School, Washington, D.C.

Rabinowitz, Mina, Cytochemistry. Graduate Student, New York University, New York, N.Y.

Rathburn, Donald, Jr., M.D., Internal Medicine. Senior Assistant Resident, Medicine, University of Virginia Hospital, Charlottesville, Va.

Ravich, Robert A., M.D., Oncology. Assistant Director, Institute of Applied Biology, New York, N.Y.

Repasky, John, M.D., Biology. Akron Hospital, Akron, Ohio.

Richards, Oscar W., Ph.D., Physiology. Research Supervisor, Biology, American Optical Company, Southbridge, Mass.

Ritchings, Edward Peyton, M.D., Medicine. Senior Physician, Victor Cullen State Hospital, Cullen, Md.

Roberts, Arlan G., B.S., Biochemistry. President, Pentex Inc., Kankakee, Ill.

Ropes, Marian W., M.S., M.D., Internal Medicine. Assistant Physician, Massachusetts General Hospital, Boston, Mass.

Rosen, Harold, M.D., Psychosomatic Medicine. Assistant Professor, Psychiatry, The Johns Hopkins University School of Medicine, Baltimore, Md.

Scholler, Jean, Ph.D., Cancer Research. Assistant, Division of Experimental Chemotherapy, Sloan Kettering Institute, New York, N.Y.

Seideman, Roy M., M.D., Preventive Medicine. Private Practice, Woodmere, N.Y.

Selkirk, G. H., M.D., Research, Pediatric Hematology. Director, Hematology Laboratory, Children's Hospital, Buffalo, N.Y.

Shane, Samuel Jacob, M.D., Internal Medicine. Medical Superintendent, Point Edward Hospital, Sydney, Nova Scotia, Canada.

Shefferman, Maurice, Dr. Op., Nutrition. President, Balanced Foods Inc., New York, N.Y.

Shister, Hyman E., M.D., Cario-vascular Disease. Attending Physician and Cardiologist, Reddy Memorial Hospital, Montreal, P.Q., Canada.

Silvermintz, Saul D., M.D., Medicine. Private Practice, St. Louis, Mo.

Simpson, Robert Anderson, M.D., Biology. Private Practice, Vancouver, B.C., Canada.

Spurr, Charles L., M.D., Hematology, Endocrinology. Chief, Medical Research, Veterans Administration Hospital, Houston, Tex.

Steigmann, Frederick, M.D., Internal Medicine. Attending Man, Director of Therapeutics, Cook County Hospital, Chicago, Ill.

Stephen, C. Ronald, M.D., Anesthesiology. Professor, Duke University, Durham, N.C.

Taylor, Dermot B., B.A., Pharmacology. Professor, Chairman, University of California, Los Angeles, Calif.

Taylor, Paul, D.Sc., Psychotherapy. Private Practice, Westcliff-on-Sea, Sussex, England.

Takahashi, William Y., M.D., Pediatrics, Psychology. Private Practice, Boulder, Colo.

Terry, Douglas Weeden, M.D., Hematology. Senior Resident, Diagnostic Clinic, Georgetown University Hospital, Washington, D.C.

Thau, Marcel, M.D., Psychology, Biology. Private Practice, Hartford, Conn.

Thompson, James Leslie, M.D., Silicosis. Director, Medical Services, Weirton Steel Company Division of National Steel Corporation, Weirton, West Va.

Thompson, William Best, M.D., Medicine. Instructor, Medicine, University of Oklahoma, Oklahoma City, Okla.

Vought, Robert L., M.D., Epidemiology, Medical Research. Associate Professor, Epidemiology, Columbia University, New York, N.Y.

Waldmann, Thomas Alexander, M.D., Leukemia Research. Intern, Massachusetts General Hospital, Boston, Mass.

Ward, Frank P., M.D., Medicine. Chief of Staff, Robeson County Memorial Hospital, Lumberton, N.C.

Yood, Harold S., M.D., Internal Medicine. Associate Attending Physician, Muhlenberg Hospital, Plainfield, N.J.